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VARIETAL RESISTANCE IN OATS TO ATTACKS BY THE STEM AND BULB EELWORM

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Since the pioneer work of Goodey (1937), interest in varietal resistance to Stem eelworm, *Ditylenchus dipsaci* (Kühn), has been stimulated, and experimental work on methods of control and the breeding of improved varieties resistant to attack by this pest is now receiving attention. As a result of more frequent cropping with susceptible crops during and since the war, damage by this pest has assumed greater intensity and importance in recent years, and the devising of good combative measures against it has become an urgent problem. In England and Wales a large number of farms are known to be more or less severely affected, and, judging from the number of new cases discovered in the last two or three years, the parasite appears to be spreading. On affected farms the seriousness of the situation is often very real ; it is usual for several of the best arable fields to carry the infestation, and recurrent failures of the oat crop have serious repercussions on the management and profitability of the farms concerned.

In view of this increasing importance of Stem eelworm as a pest of oats, it was decided in the spring of 1950 to conduct a series of experiments to inquire more fully into the potential value of resistant varieties on infested land, and to develop techniques which would be of assistance to the plant breeder in the production of new varieties resistant to the nematode. The immediate aims of these experiments were : (*a*) to compare the yields of the reputedly resistant types with those of a known susceptible type under eelworm conditions in the field ; (*b*) to develop a simple and reliable method of screening varieties for resistance, and to carry out preliminary screening tests on a large number of segregates already under selection for other characters at the Welsh Plant Breeding Station, Aberystwyth ; and (*c*) to study the manner in which resistance is inherited. Only those experiments designed to evaluate the effects of differences in varietal resistance are discussed in the present paper.

Goodey's original observations on resistance were made on seedling plants grown in short lengths of drill. The seedlings were not followed on to maturity and no comparisons were made of the yielding capabilities of resistant and susceptible varieties under field conditions. A reliable estimate of the superiority of the resistant types, as measured in increased yields per acre, was clearly essential before their use could be recommended to growers and, indeed, before a breeding programme designed to introduce resistance into new varieties could be justified. The field trials described here were designed to fill this twofold need.

INFESTATION HISTORY OF THE TRIAL FIELDS

Most of the work, both on the yields of established varieties and on the screening of segregates, was carried out in a severely infested field near Churchstoke in the county of Montgomery. This field was known to have had a history of eelworm damage since 1940, and as this provides additional

information on the bionomics and host preferences of the oat strain of *D. dipsaci*, it is given in some detail. In 1940, a crop of Black Supreme oats was severely affected, and the farmer was advised to seed the field out to a long-term grass mixture in the following year. This was done, and the field remained under grass until 1945, when another crop of Black Supreme was sown and again suffered very heavy damage. Field beans were tried in the following season and, although these were not examined, the farmer complained of a very poor crop. This is consistent with the known fact that beans may be damaged by the oat strain of the eelworm (Goodey, 1947). Subsequently, the field was sown to Montgomery late-flowering red clover and a companion crop of perennial ryegrass, which made excellent growth and provided ample grazing and good yields of seed. It is known that all varieties of red clover are attacked by *D. dipsaci*, but by a strain different from that attacking oats. In the autumn of 1949 the sward was again ploughed up and sown with winter rye, which immediately succumbed to the eelworm, and by the spring of 1950 the crop had become a total failure, thus providing further circumstantial evidence that oats and rye are attacked by the same strain of *D. dipsaci*, as suggested by Goodey (1951). After the failure of the rye, a mixture of barley, peas and vetches was sown. This made a satisfactory crop, although the proportion of vetches was found to be low, which again reflected the activities of the eelworm, as reported by Staniland and Southey (1951) and Goodey (1951).

The first yield trial with oat varieties was drilled on this field in the autumn of 1950 ; the remainder of the field which was not being used for the experiment was sown to winter wheat at the same time. All the evidence from this initial trial, and from observations on previous crops, pointed to a remarkably even distribution of infestation over the greater part of the field, and, as this was well suited to our plans for further work, about 2 acres were acquired by the Welsh Plant Breeding Station in the autumn of 1951. This area has since been used exclusively by us for resistance tests and trials. A second yield trial, put down in the autumn of 1951, was successfully completed, but a third in 1952 became, for reasons which could not be fully explained, a complete failure at an early date and yielded no data.

Another successful trial was conducted at Trelogan in Flintshire in 1951–52 on a field which had been in continuous arable cropping for some twenty years. Details of the earlier cropping of this field are not known, but in 1949 the crop was spring oats undersown with grass and clover seeds, in 1950 clover hay, and in 1951 S.147 winter oats. The trial was sown in the autumn of 1951. A slight attack by the Cereal Root eelworm, *Heterodera major*, was discovered on the trial varieties in 1952, but as all those tested are believed to be equally susceptible to this eelworm, its presence is not thought to have affected our results to any material degree.

VARIETIES TESTED

The work on varietal reaction has been confined in the main to winter oats. For the initial trial in 1950–51 at Churchstoke, four varieties—Grey Winter, S.81, Picton and S.147—were selected. The last-named variety was known from previous experience to be extremely susceptible, and was included in this and in later trials as a susceptible control variety, to provide an indication of the extent and uniformity of the infection in the trial areas, and against which resistance in the others could be measured. Of the three reputedly resistant varieties, Goodey (*in lit.*) had reported that Picton, although resistant when originally tested by him, had gone down badly to eelworm attacks in the field, and it was hoped that this trial might clarify its rather uncertain position.

Unfortunately, the seed purchased as Picton proved to be a mixture of S.147 and an unidentified spring variety. It is clear that where, in the past, Picton has been reported as susceptible, the authenticity of the variety must be regarded with suspicion.

In the second year's trial at Trelogan, the Aberystwyth-bred S.172 was added to the varieties already tested, because our screening tests had indicated that S.225, a product of a cross between S.172 and the susceptible Victory, was resistant, and it was deduced that its resistance could only have been derived from its S.172 parent. In the same year at Churchstoke, Unique and Early Grey Winter were also included, so that in this trial most of the recognized varieties of winter oats were represented. Although it was fully realized that its performance could not be strictly compared with the winter varieties, the spring variety S.225 was also put in to gain some knowledge of its behaviour in preparation for a projected series of experiments on spring oats. Care was taken that authenticated seed only was used in both the 1951–52 trials.

LAYOUT OF TRIALS AND FIELD METHODS

Randomized block designs were used in each of the three trials. The 1950–51 trial (Trial 1) at Churchstoke and the 1951–52 trial (Trial 3) at Trelogan were put down in strips each 7½ feet wide (a single width of the drill with which they were sown), with lengths of 103 yards at Churchstoke and 148 yards at Trelogan. Replication was fourfold in both. The two trials were cut by binder, the plots being threshed out separately on the fields after standing in the stooks for a few days. The 1951–52 trial (Trial 2) at Churchstoke was of the rod-row type, each plot consisting of 20-feet lengths of 5 single rows drawn with the special implement used at the Station for such purposes. The rows were 1 foot apart and were sown by hand individually with a weighed quantity of seed. Replication in this trial was sixfold. For the measurements of yields, the three inner rows in each plot were cut by hand, wrapped in paper, and after drying they were threshed out on a small thresher at the Station. Sowing, at rates of approximately 180 lb. per acre, was done about mid-October in each instance, and harvesting at varying dates in the following August. At harvest, samples of grain were taken for moisture determinations from Trials 1 and 3 and the yields were adjusted to a moisture content of 15 per cent ; in Trial 2 the grain was air-dried to constant weight before the final yield figures were taken.

At different times during the growing season information was collected on the relative densities of varieties and on the numbers of eelworms infesting them. In the two strip trials the plants in ten 1-foot lengths of two contiguous rows were dug up and counted, the sampling sites being spaced equidistantly apart along the centre of each plot according to a pre-arranged scheme. They were then bulked for each plot and later taken to the laboratory for the extraction and counting of eelworms. Plant counts were made at Churchstoke on January 24, April 24 and June 26, and at Trelogan on December 12, February 26 and May 14. In severely affected varieties the length of row dug up did not always yield sufficient plants to give efficient estimates of the mean number of eelworms in them ; where this occurred, more plants—enough to make a minimum of 20 per site at the earlier samplings and 10 at the later—were taken from adjoining lengths of the same rows. The eelworm extractions were made, therefore, on minima of 200 plants per plot early in the season and 100 later on. In Trial 2 the sampling sites were reduced to five and the plants were counted *in situ*, as the small sizes of the plots precluded the removal of samples. Consequently, no studies of eelworm numbers were made in this trial. The plant counting was carried out on December 14 and March 12. On the latter

date the drills were also graded by allotting marks ranging from 0–10 to each, according to increasing density of stand. These markings were made independently by four people, their combined totals for the five drills per plot divided by 20 being taken as the density rating of the plot.

LABORATORY EXTRACTION AND COUNTING OF EELWORMS

While the plants were still fresh the bulked samples were washed in water to which a little detergent was added, and then in running water until all traces of soil were removed. They were then chopped up finely and the eelworms extracted by means of the Baermann funnel technique. Extraction was continued overnight and the liberated eelworms were then collected and concentrated in a small volume of water by centrifuging. They were killed by warming to 70° C. in suitable bottles in a water bath, and finally fixed in formal-acetic mixture (Goodey, 1951) by the addition of an equal volume of the double-strength fixative to the water in which they were contained. While the plants were small the whole of the bulked samples could be dealt with in this way, but, as they made more growth, it became necessary to extract sub-samples only. The chopped-up bulk sample was then weighed and a sub-sample of 50 grammes was taken for extraction, by coning and quartering. By multiplying up, the number of eelworms in the bulk sample could then be estimated.

For counting, the liquid in which the eelworms were contained was made up to a known volume, agitated, and the eelworms in quadruplicate 1 cc. sub-samples were counted on Peters 1 ml. Eelworm Counting Slide (Goodey, 1951). From these counts the numbers of eelworms in the whole extract, and finally the numbers per plant, were computed. The eelworms which were extracted and counted included a large proportion—often in excess of 50 per cent—of innocuous forms, chiefly *Panagrolaimus rigidus*, and to obtain a correct estimate of the numbers of *Ditylenchus dipsaci* involved, it was necessary to correct the eelworm figures per plant for these. This was done by concentrating the eelworms again after counting in a small volume of water, staining them in bulk in 0·01 per cent cotton blue in lactophenol (Franklin and Goodey, 1949), mounting them on a slide, and then identifying a random sample of 50 or 100 of the eelworms, the mechanical stage of the microscope being used to randomize the sample. The proportion of *D. dipsaci* in the sample was then used to correct the gross numbers of eelworms per plant.

PLANT DENSITIES

Table 1 summarizes the plant density counts for the three trials. The figures given are mean counts for 20-feet lengths of drill in Trials 1 and 3, and for 10-feet lengths in Trial 2. The visual density ratings made on March 12 on Trial 2 are included.

Germination was good and uniform at all three centres and very little difference could be detected between varieties for some 8–14 weeks after sowing. In Trial 1 there was no significant difference between resistant and susceptible types at the end of January, except that the " S.147 mixture " was definitely thinner than the others, probably because of a lower level of winter-hardiness in the spring-type oat which comprised part of the mixture. In Trials 2 and 3, thinning out of the susceptible S.147 began a little earlier, its density by mid-December being significantly lower than all the others, except for Picton and S.225 at Churchstoke. At this centre the lower stand of S.225 was probably due to its inferior winter-hardiness and not, as its subsequent performance

showed, to lack of eelworm resistance, but in the case of Picton there was some susceptibility.

TABLE 1

MEAN NUMBERS OF PLANTS PER SAMPLE LENGTH OF DRILL

Variety	Trial 1 Churchstoke 1950–51 Plants per 20 feet			Trial 2 Churchstoke 1951–52 Plants per 10 feet			Trial 3 Trelogan 1951–52 Plants per 20 feet		
	Jan. 24	*April 24*	*June 26*	*Dec. 14*	*March 12*	*Rating*	*Dec. 12*	*Feb. 26*	*May 14*
Grey Winter ..	439·7	283·3	200·8	245·5	144·8	5·9	378·8	328·5	250·8
Early Grey Winter	—	—	—	275·8	167·6	8·5	—	—	—
Unique	—	—	—	273·5	174·0	8·1	—	—	—
Picton	—	—	—	212·3	106·3	4·4	403·0	379·2	238·2
S.81	416·3	196·8	176·8	276·2	151·5	8·3	356·8	332·5	239·2
S.172	—	—	—	254·8	152·8	6·8	431·3	347·0	248·8
S.147	415·8	72·5	24·3	200·6	91·5	3·9	279·3	198·0	123·2
S.225	—	—	—	229·0	102·8	4·9	—	—	—
"S.147 mixture"	315·8	76·8	23·8	—	—	—	—	—	—
Significant difference (P=0·05)	84·4	58·8	42·2	45·1	23·8	0·7	—	45·9	45·2

By March and April differences in densities were pronounced, large bare patches appeared in all S.147 plots, and these became larger and larger as the season progressed. As will be discussed more fully later, thin patches often appeared also in the resistant varieties in areas adjoining the bare patches of S.147. These thin patches in the resistant varieties were generally most conspicuous in January and February. When active growth began in the spring they filled out well as a result of increased tillering, so that differences between resistant and susceptible types became progressively more marked as the season advanced.

Although *D. dipsaci* larvae could be recovered from seedlings within a few days of their emergence, definite symptoms of damage were not apparent for several weeks. In Trials 2 and 3, "tulip-root" symptoms appeared rather sooner than in Trial 1, which is consistent with the earlier loss of plant already noted in the variety S.147 in these trials. By the end of March or early April, typical "tulip-root" conditions were always well established in S.147, and from this time onwards resistant and susceptible varieties could be distinguished at a glance. Occasionally, slight swellings were seen also in the resistant types, but these were confined to a few of the smaller and later-formed tillers and certainly never attained the frequency of occurrence, or the severity, which they did in S.147. In fact, it was not easy in the field to determine with confidence whether these slight swellings were always due to eelworm, but laboratory dissection of doubtful tillers usually revealed the presence of the parasite in fairly large numbers, as many as 20 adult *D. dipsaci* being found on several occasions in short tillers about 1 inch long. In Trial 1, evaluations were made on two dates of the proportions of plants showing swellings and these are given in Table 2.

TABLE 2

PERCENTAGE OF PLANTS SHOWING SYMPTOMS OF "TULIP-ROOT" AT CHURCHSTOKE, 1951

Variety	*April 24*	*June 16*
Grey Winter	4·5	1·9
S.81	1·7	4·8
S.147	66·3	95·8
"S.147 mixture"	62·0	94·7

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No similar figures are available for the other two trials but, in both, S.147, Grey Winter and S.81 behaved in much the same fashion as before; S.172 S.225, Unique and Early Grey Winter showed the same slight and doubtful swellings as did Grey Winter and S.81; but Picton, particularly at Churchstoke, exhibited more definite and more numerous swellings. Throughout the season, at this centre, the last variety appeared to be intermediate in character, both as regards density and development of "tulip-root", between the true resisters and the completely susceptible S.147. The symptoms shown by Picton, while characteristic and unmistakable, were never as severe as in S.147, and it is also noteworthy that far fewer plants were affected than in the latter variety, where, on many plots, practically 100 per cent of the plants were "tulip-rooted". The possibility of the diseased plants being rogues was discounted by the fact that their morphological characteristics fitted the published description of the variety.

EELWORM COUNTS

The estimated mean number of *D. dipsaci* per plant for the several varieties in Trials 1 and 3 are given in Table 3. These figures show clearly the differences in the numbers of eelworms carried by resistant and susceptible varieties from the end of April onwards, but of greater interest is the general absence of significant differences until sometime after the end of February. This suggests that initially there is very little difference in the ability of the parasite to establish itself in the tissues of resistant and susceptible seedlings, and that resistance does not prevent the entry of the eelworm into the plant. In areas of very heavy infestation, large invasions of infective larvae actually killed off seedlings of resistant varieties at an early stage of growth and resulted in the thin patches which have already been noted.

TABLE 3

MEAN NUMBERS OF EELWORMS PER PLANT

Variety	Trial 1			Trial 3		
	Jan. 24	*April 24*	*June 26*	*Dec. 12*	*Feb. 26*	*May 14*
Grey Winter	1·6	6·1	2·9	1·6	1·3	45·0
Picton	—	—	—	2·6	1·8	88·5
S.81	1·2	5·3	2·5	1·5	1·5	69·4
S.172	—	—	—	1·9	1·8	25·8
S.147	1·9	14·9	143·7	4·9	4·2	638·0
"S.147 mixture" ..	1·6	17·8	178·5	—	—	—
Significant difference (P = 0·05).. ..	—	7·8	80·4	—	—	147·8

The figures given in Table 3 are probably underestimates of the numbers of eelworms actually present, as the Baermann funnel technique does not give fully efficient recovery. Considerable numbers of eelworms die through lack of oxygen or other causes before they are able to free themselves from the plant tissues, and consequently are not collected. The figures presented, therefore, cannot be considered as representing the total eelworm burdens of the plants, but, since all stages of the extraction procedure were carefully standardized, they give reliable estimates of the relative numbers in the respective varieties as sampled on any particular date. The fully susceptible varieties are subject to underestimation for another reason. As soon as infected plants began to die out and disappear, it was clear that, on any one date, only the relatively less severely affected survivors were being sampled, and that, as the season progressed and the stands became increasingly thinner, the samples contained more and more plants which had escaped infection or which had suffered infection

comparatively mildly or late in the season. As a result, the methods used have underestimated the magnitude of the difference between resistant and susceptible varieties.

YIELDS

As an indication of the relative performance of some of the varieties in the absence of eelworm, data collected from a rod-row yield trial conducted at the Welsh Plant Breeding Station are included in Table 4. The yields from the two rod-row trials are given in grammes per plot, and also in hundredweights per acre to give an indication of the results on an acreage basis.

TABLE 4

MEAN YIELDS OF GRAIN

Variety	Trial 1	Trial 2		Trial 3	Station Trial	
	cwt. per acre	*grammes per plot*	*cwt. per acre*	*cwt. per acre*	*grammes per plot*	*cwt. per acre*
Grey Winter	16·3	1,508	21·8	19·5	1,510	23·8
Early Grey Winter ..	—	1,821	26·3	—	—	—
Unique	—	1,720	25·0	—	—	—
Picton	—	1,081	15·6	18·6	1,269	20·0
S.81	15·4	1,752	25·3	18·9	1,562	24·7
S.172	—	1,620	23·4	15·3	1,707	27·0
S.147	1·8	785	11·3	3·8	1,779	29·1
S.225	—	1,168	16·9	—	—	—
"S.147 mixture" ..	2·7	—	—	—	—	—
Significant difference (P = 0·05).. ..	1·9	221	3·2	4·0	215	3·4

Severe bird damage on Trial 1 while the crop was standing in the stook caused an estimated loss of grain of at least 25 per cent. When a correction is made for this, the mean yields of the varieties in the order in which they appear in Table 4, become 21·7, 20·5, 2·4 and 3·6 cwt., which brings the results more into line with those of the other trials. S.147 gave relatively better results in Trial 2 than in the others, but this was due partly to a lower level of infestation in some of the six blocks which comprised the experiment. The yield of Picton in the same trial was low, which agrees with the loss of plant it suffered and the symptoms of "tulip-root" which it showed at this site. S.172 yielded poorly in Trial 3 because fertility conditions on this trial field were not suitable for its best performance.

From the foregoing it is clear that S.147 is particularly susceptible to Stem eelworm attacks and should never be used on land known to be infested. Picton occupies a doubtful intermediate position; and all the others, including the spring variety S.225, are resistant and capable of yielding sound economic returns, even on severely infested land. The success of these varieties in the very stringent tests to which they were exposed makes possible the successful cultivation of oats on severely infested land. It also underlines the desirability and the practical utility of incorporating resistance to the eelworm in future oat breeding programmes.

THE NATURE OF RESISTANCE

While these experiments were not designed to inquire critically into the nature of resistance, useful circumstantial evidence has emerged which throws some light on this problem. It has already been stated that at first little

difference is apparent in the numbers of *D. dipsaci* recovered from resistant and susceptible seedlings. This means that resistance does not entail the inability of the parasite to invade resistant seedlings. It has also been pointed out that in areas of very heavy infestation, where a complete, or nearly complete, loss of S.147 plants occurred, parallel thinning out of the resistant varieties was also observed. In Trial 2, at Churchstoke, pronounced differences in infestation existed between blocks, and it is possible to express numerically the similarity in the behaviour of resistant and susceptible varieties at different levels of infestation. In this trial, blocks I, II and IV carried very high infestations (as measured by the development of symptoms in S.147), block V a moderate one, and blocks III and VI comparatively mild infestations. Table 5 summarizes the data collected for S.147 from these blocks and correlates them with the means of similar data for the resistant Grey Winter, Early Grey Winter, Unique, S.172 and S.81. Data for Picton are omitted from this comparison because of its doubtful position as regards resistance, and those for the spring variety S.225 because of its lack of winter hardiness.

TABLE 5

COMPARISON OF THE PERFORMANCE OF S.147 AND THE RESISTANT VARIETIES IN THE SIX BLOCKS OF TRIAL 2, CHURCHSTOKE, 1951–52

Block	Density Ratings March 12		Plant Counts Dec. 14		Plant Counts March 12		Yields in grammes per plot	
	S.147	Resisters	S.147	Resisters	S.147	Resisters	S.147	Resisters
I ..	3·5	6·1	123	227	45	150	898	1,749
II ..	2·3	6·7	188	249	78	144	507	1,603
III ..	6·3	8·3	253	299	127	179	1,113	1,661
IV ..	1·5	6·3	137	229	54	120	369	1,687
V ..	4·3	8·1	223	263	99	167	997	1,741
VI ..	5·8	8·3	280	324	146	189	807	1,678
Correlations ..	$r = +0·94$		$r = +0·96$		$r = +0·89$		$r = +0·43$	

The loss of plant was never as marked in the resistant varieties as in S.147, but their densities showed obvious and significant positive correlations with those of the latter. In Trial 3 at Trelogan, similar variations in infestation occurred in broad bands across the blocks and, although figures cannot be given here, it was quite obvious that in this trial also a definite thinning out took place in the resistant varieties, as well as in S.147, in the areas of greatest infestation. At both sites this thinning out happened early in the season, before pronounced symptoms of " tulip-root " appeared in S.147, and before significant differences developed in the eelworm burdens of resistant and susceptible varieties. Very little, if any, breeding of eelworms within the host tissues had taken place by this time, and it is reasonable to suppose that these early losses were caused by invasions of infective larvae in sufficient numbers to cause the death of the plants. Since resistance does not prevent the entry of the parasite into the seedlings, and since, at first, similar numbers of eelworms are found in resistant and susceptible varieties, it follows that both types may be killed off in this fashion. Resistance, even in the best types, is therefore not complete in the early stages of growth, although its beginnings are discernible from the start because the resistant varieties never react quite as violently as S.147 to this early attack.

Resistance becomes more pronounced and more clearly expressed later in the season, when active plant growth and eelworm multiplications begin. At this stage the susceptible varieties develop strong symptoms of attack, suffer further rapid loss of plant, and become progressively thinner thereafter throughout the season. The resisters show little or no " tulip-root ", suffer

no further loss of stand, and generally tiller out well in the initially thinned patches to produce a full crop. This is shown by the yields column in Table 5. The absence of a significant correlation between the block yields of S.147 and the resistant varieties illustrates the difference in the performance of the varieties at this stage. At about the same time, significant differences begin to appear in the eelworm burdens of the varieties, so that resistance is associated with differential rates of multiplication of the eelworm in resistant and susceptible varieties. The reaction of the plant to infection—the production of "tulip-root"—also enters into the picture at this stage, but whether this is the cause or the effect of the rapid multiplication of eelworms in susceptible tissues is not known.

The absence of complete resistance early in the season gives rise to some concern. Survival while the seedlings are still very young appears to be linked with the level of infestation to which they are exposed, and the question which naturally arises is whether a level may be reached where even the resistant varieties may succumb completely or, alternatively, whether moderate infestations under unfavourable conditions of soil, climate or season may result in failures. A warning must be given, therefore, that in certain circumstances, particularly where extremely heavy eelworm infestations and unfavourable growing conditions coincide, failures may follow the use of resistant varieties, but the risk is probably not great.

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THE EARLY HISTORY OF A POTATO BLIGHT EPIDEMIC

by J. M. HIRST

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The growth of *Phytophthora infestans* from diseased potato tubers into sprouts was first demonstrated by de Bary (1863)—an important discovery that was not achieved easily. Murphy and McKay (1927) say that it came only after many years search, and, in summarizing later investigations, they conclude " that four investigators only in the last sixty-five years have been able to connect the first appearance of blight in the open with the emergence of diseased shoots, in spite of widespread search ". Since 1927 the phenomenon has been reported by Limasset (1939), Limasset and Godard (1941), Peterson (1947), and Keay (1953, 1954). Their results confirm the claim by Murphy and McKay that stem lesions occur most frequently at 25° C., and are rare out of doors but easily produced in heated glasshouses.

Mycelium overwintering in diseased tubers is generally thought to be the most important source from which epidemics start. Its real importance will be known only when we have reliable evidence about both the frequency with which the fungus growing from a diseased tuber causes aerial stem lesions, and the area over which the fungus can spread from such primary lesions. Forecasting potato blight from meteorological observations implies that the fungus is always present; it assumes that sporangia will be formed, dispersed and cause infections when certain weather occurs. A single flush of infections from the primary lesion, however, is very unlikely to spread the fungus enough for it to be generally distributed in crops. Müller and Haigh (1953) suggested the need for about five " generations " of infections. Improved timing of control measures depends largely on knowing the primary source of inoculum, the weather conditions required for infection, and what happens in the cryptic phase of the epidemic from the first production of sporangia to the discovery of a generalized outbreak. About 12,000 tubers are normally planted per acre and only a few will contain blight. As it is obviously impractical to make detailed observations on the origin of outbreaks in such conditions, in 1954 a small plot at Rothamsted Experimental Station was planted with potatoes which contained a high proportion of diseased tubers. Every plant was examined each week from emergence until the end of July, and records were made of the weather and the occurrence and spread of the fungus.

DESCRIPTION OF EXPERIMENT

On April 13, 1954, a plot approximately 40 × 10 yards was planted with nine rows of potatoes spaced 28 inches apart, and with 82 tubers spaced accurately 16 inches apart in each row. Rows A, B, D, F, H and I (*see* plan, Fig. 1) were guards planted with healthy, unchitted Majestic tubers. Rows C, E and G were planted with chitted tubers infected with *P. infestans*. All the tubers in row C and 35 at the west end of row E were of the variety Ulster Cromlech, half of these being inoculated with *P. infestans* on February 8 and half on March 3. On each occasion half were inoculated at the rose end and half at the heel end. The east end of row E contained 47 naturally infected Majestic tubers; row G contained 13 King Edward and 69 Ulster Chieftain tubers, all naturally infected in 1953. To facilitate inspection, the rows were not ridged—a departure from

normal practice that may have allowed more very weak sprouts to emerge than is usual from naturally infected tubers.

All tubers had live sprouts when they were planted, but their condition varied considerably. Blight lesions on the Ulster Cromlech tubers covered about half their surface, those inoculated at the rose end having fewer live sprouts; 8 per cent of the Ulster Cromlech tubers did not produce a sprout that emerged above ground; 4 per cent of the naturally infected Majestic tubers did not produce an emergent sprout; King Edward and Ulster Chieftain tubers suffered from other rots as well as blight, and 16 per cent failed to emerge.

EARLY INFECTIONS

On May 28, when a lesion was first seen, most of the chitted, diseased tubers had produced sprouts up to 6 inches high; fewer of the healthy Majestic plants had appeared and the mean height of those which had was less than 2 inches. The fungus was first found on a shoot 3 inches high, produced from an Ulster Cromlech tuber (plant C23) which had been artificially inoculated in the rose end on March 3, 1954. The lesion affected the whole shoot, extending from well below ground to the apex. The base of the stem was not girdled and the basal leaf, growing from the healthy sector, was not infected. The next two leaves showed typical blight lesions spreading from the stem lesion along the petioles and into the laminae. The apical rosette of leaves and the meristem had already been killed by *P. infestans*, which was sporulating slightly on all lesions. By June 3, the whole shoot was dead, except for the basal leaf and the portion of stem to which it was attached; a weak but apparently healthy shoot 1¾ inches long had grown in its axil. On June 9, the lamina of the basal leaf had become invaded by the fungus growing along the petiole, and a lesion on the axillary shoot extended from its base almost to its tip. On June 9 and 10 all these parts bore sporangia of *P. infestans*.

The earliest secondary infections were found in row E, presumably because the small Majestic plants in the intervening row D escaped infection. On June 9, when the single shoot of plant E37 was 10 inches tall, the sixth leaf up, about 7 inches above ground level, had a single lesion on its mid-rib. The lesion was a long one, and the fungus was spreading into the laminae of five primary leaflets, one of which was nearly dead. Neither the stem nor the petiole of the infected leaf was attacked. The infection was almost certainly caused by an airborne sporangium. When examined on June 15, the infected leaf had fallen but was still sporulating on the ground. On June 11 a similar lesion was found on plant E22, affecting the mid-rib and four primary leaflets of one leaf. The infections on E37 and E22 appeared to be of the same age; on neither plant was the stem infected until a late stage in the attack, and then only at some distance above the ground. On June 14 numerous small lesions were found, chiefly on the lower leaves, on plants C23, E22 or plants close to them; but none was observed near plant E37. Subsequent flushes of infection became progressively larger, causing more lesions and infecting more plants, and led to an obvious patch of diseased plants. This phase of the outbreak is best described by Figs. 1 and 2.

Apart from plant C23, only one other showed a lesion suspected to have arisen from its parent tuber. This Ulster Cromlech tuber (C6) was also inoculated in the rose end on March 3, and the lesion was first observed on July 6, when there was a small group of plants near it already infected. By July 15 foliage infections on the plot were so many that this plant could be lifted without materially altering the amount of inoculum. *P. infestans* was

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present in the stem below ground, but this was inconclusive evidence of the origin of the stem lesion, because no connection could be found between the lesion and the fungus in the parent tuber. If this one is also accepted as developing from fungus in its tuber, only two such infections developed from the 246 diseased tubers planted.

The three weeks after planting had less rain than the average, more sunshine, a slightly higher soil temperature, and the air temperature was considerably below average. The shoots from diseased tubers emerged about ten days before those from healthy tubers, presumably because they had been chitted. Emergence continued for four weeks (Fig. 3), during which the weather

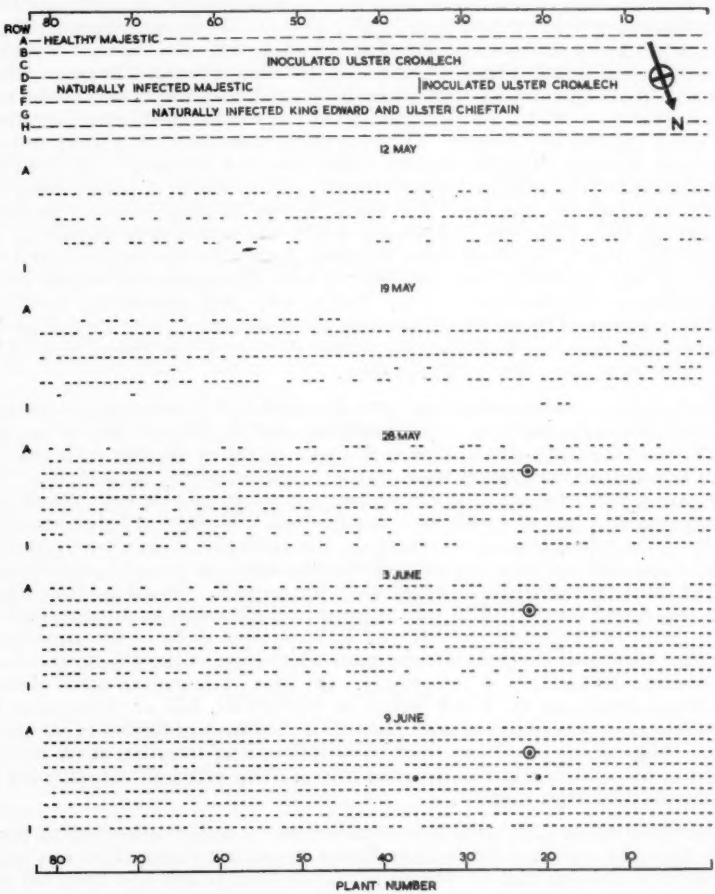

Fig. 1. Plan of experiment and position of emerged and infected plants between May 12 and June 9, 1954. (Emerged plant -. Infected plant with stem lesion ⊙. Infected plant, lesions on foliage •).

was consistently cool and dull with average rainfall, except for the second week of May, which was warm and dry. The first infection was found after a short spell of warm and thundery weather, at the end of which, on May 28 and 29, conditions at screen height (4 feet above ground level) nearly reached those specified by Beaumont (1947) as critical for the development of potato blight. At " crop level " (defined as level with the top of the ridges and vertically above the top of the furrow) in a crop of Majestic less than a quarter mile away, relative humidity was continuously over 75 per cent, but the temperature was much too low to satisfy Beaumont's requirements. In June and July soil temperature was 1–3° F. below the long period weekly averages, and air temperature was 0–6° F. below (except in the second half of June, which was dry with average temperature). Low sunshine throughout the period, together

Fig. 2. Position of emerged and infected plants between June 16 and July 22, 1954. Symbols as in Fig. 1.

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with heavy rain in the second week of June and the first and third weeks of July, resulted in long periods of unseasonably wet weather. The occurrence of Beaumont warning periods is shown in Fig. 3.

New infections first appear as minute necrotic lesions, which normally occur in flushes, each representing a single spell of weather suitable for infection. Crosier (1934) showed that the incubation period of the fungus and the rate at which lesions expanded were determined by temperature. With experience it is possible to estimate the date of infection from the time lesions appear,

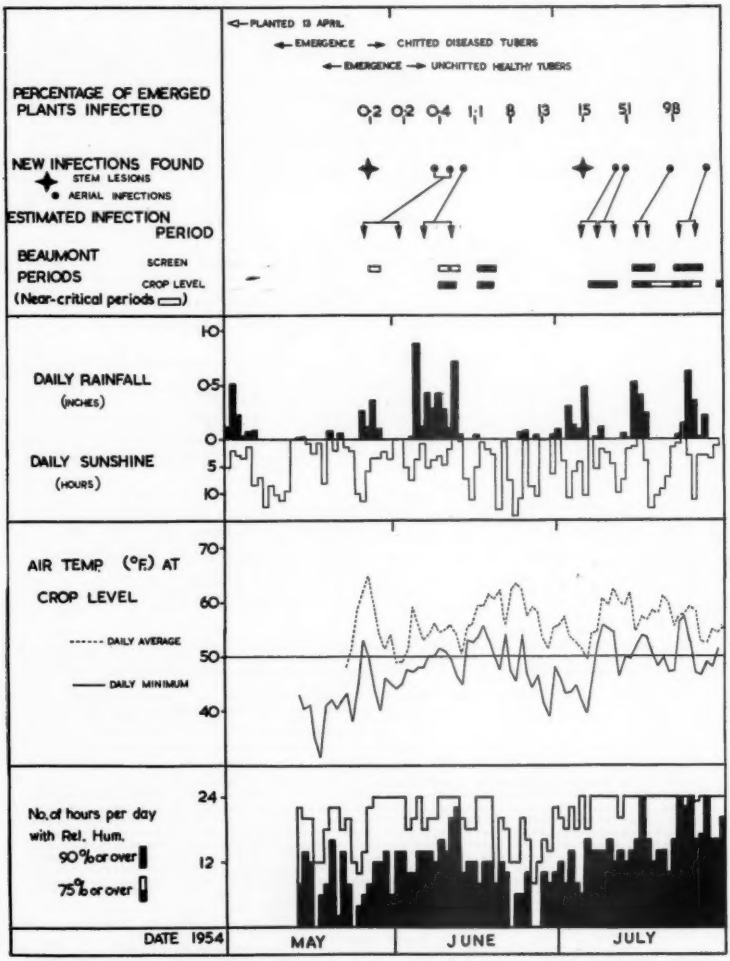

Fig. 3. Date of infection, appearance of lesions, and associated weather.

their size and the preceding weather. Dates when flushes of new lesions were noted, and the contemporary estimates of infection period, are shown in Fig. 3. Comparison of these with the percentage of plants infected suggests that the observed flushes account for all the increases in the percentage of infected plants, except the last two in June. The appearance of these lesions was not recorded. Five of the six estimated infection periods were associated with Beaumont warnings at crop level ; the other (earliest) included a long spell when the relative humidity was continuously over 75 per cent, but the temperature at night was much too low to satisfy Beaumont's requirements. The increased percentage infection of plants in late June probably resulted from infections in the warning period between June 16 and 19.

DISCUSSION

No single experiment can be expected to explain the long-standing problem of how Potato Blight epidemics start. The dearth of detailed observations, however, justifies describing an experiment which was, in many ways, inconclusive. Experiments by Limasset and Murphy and McKay suggested that the disease might originate from mycelium spreading through the soil from dead tubers, or from shoots killed before they came above ground. My experiment provided no evidence to support this. All infections could be traced to diseased shoots produced from diseased tubers. Diseased shoots, however, were produced only by artificially inoculated tubers, and by less than 1 per cent of all diseased tubers planted. Previous tests in the glasshouse with artificially inoculated and naturally infected King Edward tubers had suggested that they behaved similarly. Further experiments are required to confirm this and to study quantitatively the production of diseased sprouts in years with average or higher temperatures. If the results of this experiment are typical, seed stocks containing 1·0 per cent or 0·1 per cent of blighted tubers would produce, when planted, one infected shoot in every acre or ten acres, respectively. The primarily infected shoots are so few and inconspicuous that it is hardly surprising they are rarely found before secondary spread attracts attention to their position, and by then their origin from tubers is equivocal.

In 1954, local infections, which were produced at frequent intervals, clearly marked the position of the primary source before blight became general in the district. At this time plants close to the primary source were more than half defoliated, while plants at a distance carried only a few lesions. If such behaviour is typical, it is difficult to understand why such foci are not reported more frequently. Until mid-July, infections were restricted to a fan-shaped area down-wind from the first infected plant, and so far as could be determined from this rather unsuitably shaped plot, spread was limited to short distances, possibly as a result of the small quantity of sporangia produced, or by the weather.

To reduce the number of premature forecasts of the date of regional disease outbreak, Grainger (1950) and Large (1953) found it necessary to ignore Beaumont warnings before some "zero date" which has been derived empirically. This experiment shows that infections nearly always occur during crop-level Beaumont warnings, including the "premature" ones in June. Beaumont suggested that blight would be found 2–3 weeks after the first warning, but this may be too short an interval to allow the fungus to spread sufficiently from the true initial sources to be found generally distributed in crops. In 1954, a wet year, this phase occupied two months, during which time there were six flushes of infection. The zero date necessary in practical

forecasting may perhaps have biological significance if it generally represents the date when distant spread replaces local spread around a primary source of the fungus.

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STAR CRACKING OF APPLES IN EAST ANGLIA

by J. E. E. JENKINS AND I. F. STOREY

National Agricultural Advisory Service, Cheshunt, Herts, and Cambridge

During the years 1951–53 the presence was noted in fifteen apple orchards in the Eastern Province of isolated trees, or groups of trees, showing an unusual unthrifty condition, which could not be attributed to fungus disease, unfavourable soil or cultural factors. The trouble was to be found in some of the best orchards and was not confined to those where the growth was poor or the trees old. The affected trees come into growth late in the spring and the number of flowers produced is small and only a few fruits mature. Because of this, the branches of seriously affected trees tend to be more upright in habit than those which have fruited heavily in the past. A striking feature to be found in those trees which do make good leader growth is a die-back of this growth during the

winter. This is followed by the development of buds lower down the shoot (Plate I, 2) and by the production of shoots from buds arising at unusual places on wood of all ages, so that by late summer the trees show a profuse development of young shoots. Very often blister-like lesions are present on the one-year-old wood, and these frequently develop around the buds and nodes. The affected area has a sharp margin, and the bark covering it, which may be blistered at first, later disappears. These bark lesions persist on the older wood (Plate I, 1).

During the past three years, shoots showing die-back and bark lesions have been examined frequently for the presence of a fungus but, generally, no fungus developed from the dead tissue. The affected trees have shown these characteristic symptoms every year for the past three years and, according to some of the growers, for at least six years. The die-back does not seem to be associated with the particular weather of any one winter. The age of the trees was anything from ten to forty years old. The profuse development of young shoots suggests that the trouble may have affinities with the proliferation disease described by Bovey (1953) or the " Scopazzi " of Refatti and Ciferri (1954).

In the autumn of 1953 Mr. K. V. Cramp showed us one of these trees in a Bramley orchard at Orwell in Cambridgeshire, on which the fruit showed very characteristic " star crack " markings. The fruits tended to have an irregular shape, particularly where the cracks were deep. In the late summer of 1954 all the problem trees mentioned above were examined and in every instance fruit showing the characteristic star cracks could be found. In addition, trees showing the same fruit condition were located in fourteen more orchards, but only in a few of these was the die-back of the leader growth seen. Some of the orchards consisted of cordon trees which had been very heavily pruned, and in others the trees were old and had made practically no leader growth. The majority of trees were of the variety Cox's Orange Pippin, and in severely affected fruit the cracks were deep and the fruits small and distorted. However, the bulk of the affected fruit of this variety was of normal size and not distorted, most of the cracks being around the calyx end of the fruit (Plate I, 4). Cracks on the side of the fruits were always the largest and deepest (Plate I, 3). These markings are quite distinct from the russetting and cracking caused by spray, weather or scab injury. Fruit symptoms have also been seen on the varieties Early Victoria (syn. Emneth Early), Charles Ross, Laxton's Fortune and Monarch. Only isolated trees were affected in most orchards, but there were several in which a number were found. An attempt was made in these latter orchards to see if there was any sign of the condition spreading from tree to tree.

In an orchard at Hadleigh in Suffolk consisting of 199 Ellisons Orange, 27 James Grieve, and 300 Cox's Orange trees—of which 151 were on a Malling type rootstock and 149 had been top-worked on to trees of the variety Gladstone —the trouble could only be found affecting the Cox's Orange. Of 21 diseased trees, 20 were ones which had been formed by top-working on to the Gladstone by the grower himself. An examination of the trees in the orchard from which the graft wood was obtained showed that a small proportion of the trees were affected with this same condition. It may be significant that the one Cox's Orange tree on the Malling rootstock which was affected was adjacent to a diseased tree of the other series.

At Langham, Essex, an orchard comprised mainly of Cox's Orange contained one row of twelve trees of Beauty of Bath. These twelve trees were top-worked with Cox's Orange in 1948, and four of the trees in 1954 showed both vegetative and fruit symptoms, although all branches were not affected. The scions had been obtained from an orchard in which at least one tree was diseased.

Another Langham orchard consisted partly of forty-one rows of dwarf pyramids, mainly of the variety Cox's Orange, with forty trees in each row. Die-back had been reported from this orchard, and although *Gloeosporium perennans* had been associated with the trouble, in the main no fungus could be isolated from the dead wood. Trees showing the fruit symptoms were recorded in early October 1954. Affected trees occurred in rows 1, 4 and 29, and wherever the trouble was present several adjacent trees were also affected. The number of trees in each group showing the symptoms were respectively 6, 4, 3, 6, 12 and 2. No isolated affected trees were found and there was no evidence of spread across the rows. Branches of adjacent trees had been tied together and a large number of natural grafts had formed, so that it was impossible to distinguish individual trees.

Observations in the orchards at Hadleigh and the first Langham orchard would suggest that the trouble was transmitted with the graft wood, but the possibility of Gladstone and Beauty of Bath having been affected before top-working cannot be ruled out. However, as in some trees only individual branches were affected, this would suggest that graft wood is in fact responsible. Since affected trees produce an abundance of young wood, graft wood may have been selected from these trees before the trouble was recognized. The distribution of the disease in the third orchard suggested spread from tree to tree, the natural grafts forming the means of transmission.

In New Zealand a disease known as "green crinkle" (Atkinson, 1946) produces symptoms on the fruit which appear to be similar to the star cracks we have found, but there is no indication of any die-back or other sign of abnormal growth. In Canada a virus disease known as "false sting" has been reported (Hockey, 1941) in which the apples are deformed, but here again no reference is made to fruit cracking or to foliage or bark symptoms. Recently, Ramsfjell (1952) in Norway has noted a star cracking of the apple fruit which has become abundant in that country and is probably similar to the trouble described here. The cause is not known, but he suggests that a virus related to false sting is responsible. We see no reason to dispute this view, and it may well be that false sting, green crinkle, star cracking and proliferation diseases of apple, even if not due to the same virus, may be found to have some part of the virus complex in common.

As the information suggests that the trouble can be transmitted, graft wood should not be taken from trees showing these symptoms. If fruit is not available, it would be prudent to discard trees showing too profuse a development of young shoots, especially if signs of die-back are also present.

We wish to thank Mr. K. V. Cramp, Mr. R. W. Rennison and Mr. A. D. Todhunter for bringing this problem to our notice and for their help in its investigation; Mr. H. Wheeler for the photographs; and Dr. I. Prentice for much help in searching the literature of these virus diseases of apples.

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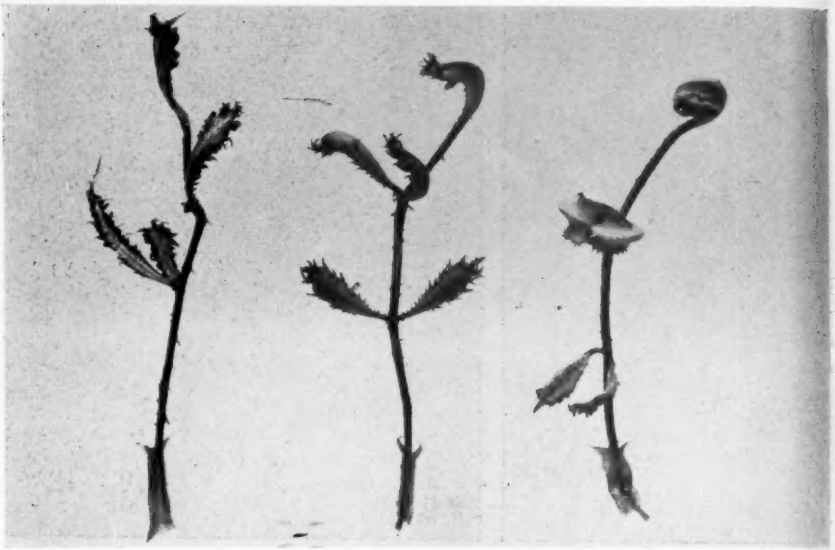
1. Lesions on two-year-old wood. Cox's Orange Pippin.

2. Die-back and proliferation on Cox's Orange Pippin.

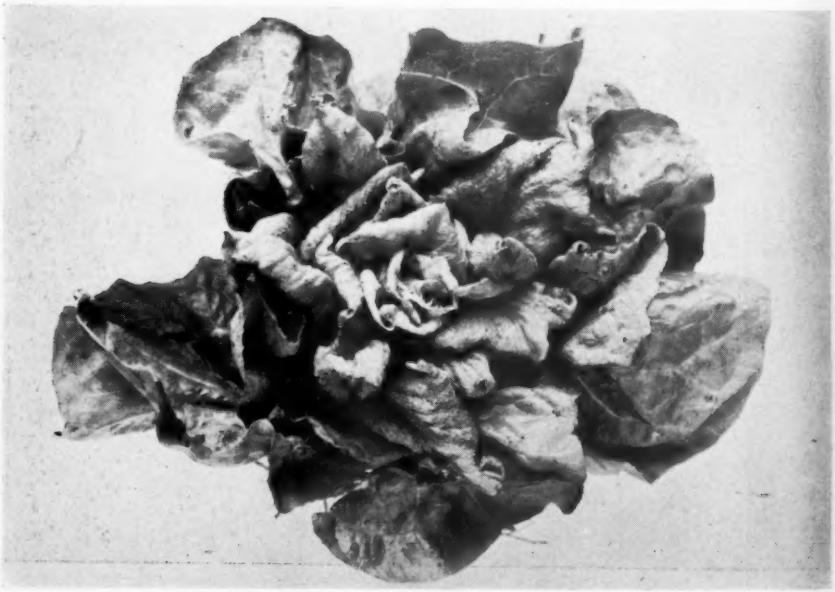
3. Star cracking on Bramley's Seedling. Orwell, 1953.

4. Typical star cracking at calyx end. Cox's Orange Pippin.

PLATE I



1. Rambler rose leaves showing typical narrowing of leaflets and increase in depth of marginal serrations.



2. Lettuce showing typical thickening and distortion of inner leaves, giving "dogs tongue" effect.

PLATE II

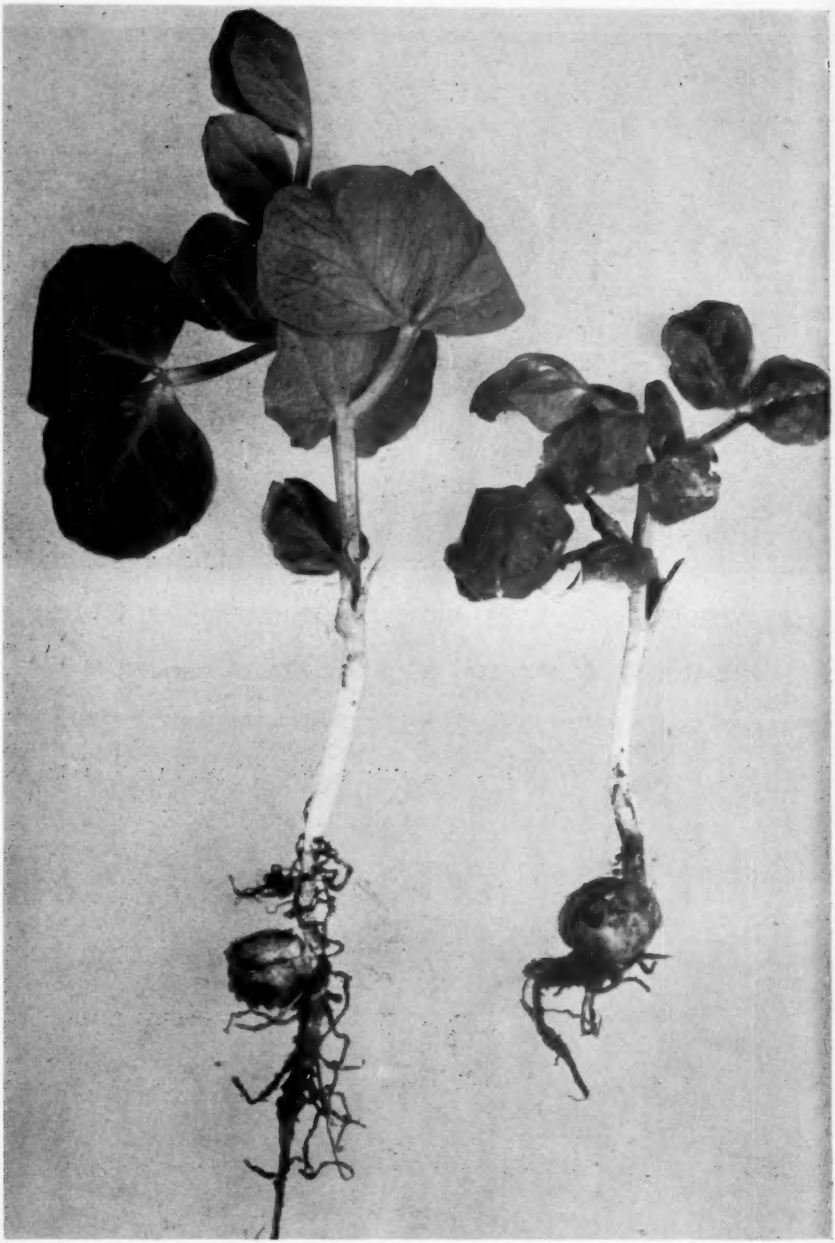
PERGAMUS SP. ON POTATO ROOTS (see p. 71)

1. Potato roots bearing (*left*) immature cysts of *Heterodera rostochiensis*, and (*right*) eggs of *Pergamus* sp. × 5.

DAMPING-OFF AND LEAF BLIGHT IN AZALEA (see p. 71)

2. Typical appearance of young plant attacked by *Rhizoctonia solani*, showing dead leaves attached to stems by strands of mycelium.

PLATE III



Left : normal plant, after mangolds ; *Right :* thrips infested plant after radishes, showing reduction in size and blotching of leaves.

PLATE IV

THRIPS ANGUSTICEPS UZEL ATTACKING PEAS

by H. C. GOUGH

National Agricultural Advisory Service, Cambridge

On many occasions during the period 1948–53, *Thrips angusticeps* Uzel has been found attacking peas in East Anglia. The damage is usually seen in April, when the crop is 3–4 inches high. The first impression is of a setback to growth accompanied by yellowing, but closer inspection shows that the leaves of the attacked plants are puckered and blotched with yellow. The silvering, usually so typical of thrips damage, is not always obvious. The lower leaves may be dried up and wrinkled in a severe attack, and thrips have been found underneath the epidermis of the leaves. In the field in the early stages of attack the thrips are easy to find, particularly in the young folded leaves, but they are often absent on plants which have been removed from the field and not placed immediately in a closed container. In a severe attack, most of the plants in a field may be affected and there is a marked difference in colour and size of attacked and healthy plants (see Plate IV). During May the thrips decrease in numbers, and by the end of the month it may be difficult to find any. The plants will then usually recover, though flowering and podding may be delayed and the yield reduced.

One of the most characteristic features of the attack is its association with certain previous crops. On one occasion a field of peas after mustard was seriously affected, but an adjoining field where the crop followed potatoes, was free, although it had been sown with the same seed and was otherwise practically identical. On another farm peas after linseed were attacked, but not after oats. Most attacks have been recorded after brassica crops or linseed, but attacks have occurred after daffodils, mangolds for seed, and barley. It is possible, of course, that in some of these instances the thrips had been feeding on a weed rather than the crop. The occurrence of damage after certain previous crops has also been noted by Mühlow (*Växtskyddsnotiser*, 1944, (4), 58–9) and other writers. It is explained by the observation of Buhl (*Anz. Schädlingsk.*, 1934, **10,** 31–4) that *T. angusticeps* hibernates in the soil as a micropterous form incapable of flight. It cannot therefore move far when it emerges in the spring and must feed on whatever food is available. Doeksen (*Tijdschr. PlZiekt.*, 1938, **44,** 1–44) implied that attacks on peas after flax were well known in Holland.

According to Morison (*Ann. appl. Biol.*, 1943, **30,** 251–9), the species is widely distributed, especially in the southern half of Great Britain. He quotes records of attacks in various European countries on Brassicae (several species), flax, peas, beet and oats. Hukkinen and Syrjänen (*Ann. ent. Fenn.*, 1941, **6,** 115–28) also reported damage to lettuce in Finland.

In light attacks control is unnecessary, but on one heavily attacked field dusting with 5 per cent DDT was advised and it appeared to give good control, although this may have coincided with the natural migration of the pest. Sylvén (*Växtskyddsnotiser*, 1949, (3), 1–4) found DDT as a spray, and a dust containing DDT and BHC, to be unsatisfactory, but reported that parathion gave an excellent control.

I am indebted to Dr. Guy Morison for the identification of the first specimens and for much helpful information, and to Mr. W. E. Dant for the photograph.

GREY MOULD OF ANEMONES IN CORNWALL

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AND KATHARINE H. JOHNSTONE

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One of the worst troubles encountered by the grower of anemones in Cornwall, and to a lesser extent in Devon, is Grey Mould, caused by *Botrytis cinerea* Fr. Certain areas, notably the Falmouth district and some valleys near the south coast, seem particularly favourable for the growth of the fungus, probably because of their local climate. The cultivations in the Tamar Valley, however, are usually comparatively little affected.

SYMPTOMS OF THE DISEASE

Infection of the anemone leaf usually follows injury of some kind, the first signs of *Botrytis* attack being a reddish-brown coloration of the damaged area. The fungus progresses rapidly within the invaded tissues and the whole leaf eventually becomes a blackened, sporulating mass. The green bracts beneath the flower may also be invaded but, in our experience, direct infection of uninjured leaf and stem tissues does not normally occur. Petals and moribund leaves are readily invaded, however, and this constitutes the greatest danger. Infection of the petals quickly renders flowers unmarketable, and buds growing through *Botrytis*-infected leaves may fail to develop at all. Moreover, once the fungus has gained a foothold in the plant, complete collapse commonly results, including death of the crown.

CONDITIONS OF INCIDENCE

Grey Mould is essentially a trouble of well-grown anemone crops in districts potentially suitable for the production of the highest quality flowers. Its incidence is associated with several predisposing factors—the degree of mechanical damage, the physiological condition of the plants, climate, and the prevalence of the pathogen—but all these factors are closely interrelated.

The anemone plant is very subject to injury, especially when unduly leafy, and any damaged tissue is liable to invasion by *Botrytis*. One of the most frequent sources of damage is wind ; an autumn or winter gale results in dead scorched tips and margins of many leaves and floral bracts. Other types of damage are caused by careless hoeing, injudiciously applied top dressings and bruising of the plants during picking. Apart from definite injuries such as these, many anemone leaves become necrotic during the winter. Some of this necrosis is the result of attack by other fungi—for example, by *Peronospora ficariae*—while some is undoubtedly of virus origin. It is noteworthy that the necrotic areas caused by *Peronospora* are seldom invaded by *Botrytis*.

In Cornwall anemone corms are planted mainly in June and early July, the growth during the summer varying considerably from year to year. Under favourable growing conditions a soft, leafy plant develops, often with an insufficiently extensive root system. A similar type of plant can also result from the excessive use of quickly available nitrogen at planting time or from too close planting in the rows. In the autumn, when soil nitrogen is much reduced

* Now at N.A.A.S., Cambridge.

by leaching, such unbalanced plants develop a yellow-green colour and the lower leaves become moribund. *Botrytis*, once established on these leaves, spreads quickly in favourable weather.

The name " Winter Browning " covers a number of pathological conditions, most of which appear to be due to growing the anemone plant out of season. In one form of the trouble the foliage becomes lax and finally prone, the petioles having buckled and lost their turgidity near the point of attachment to the corm. A rot, in which *Botrytis* is often concerned, frequently sets in at this point and is particularly dangerous because of its proximity to the heart of the plant. In general, however, this type of collapse is rare before December, by which time the spread of *Botrytis* is usually less speedy than earlier in the season.

None of these predisposing causes is likely to be followed by Grey Mould in epidemic proportions, unless the weather is also favourable to the fungus. In our experience, the disease is seldom serious before October or after January. The worst epidemics in recent years—1948, 1951 and 1953—occurred when damaging gales in September were followed in October by warm periods of very high atmospheric humidity. In such circumstances, a thick leafy anemone crop provides ideal conditions for the spread of *Botrytis*.

In all probability the fungus itself is usually present in the autumn in sufficient amount to start an epidemic when environmental conditions are favourable. There is no clear evidence that the risk is appreciably increased by such unhygienic practices as throwing down unwanted flowers in the picking paths or stacking them in heaps at the edges of the field, even though these flowers sometimes become covered with sporing *Botrytis*. Such relatively small or local sources of infection may not be important, but there is little doubt that the proximity of a large source of spores is dangerous, and it is probably significant that strawberries are another main crop on many of the holdings where anemones suffer regularly from Grey Mould. The variety Auchincruive Climax, on which fruit—much of it covered with *Botrytis*—may be present throughout the autumn, is a particularly prolific source of spores.

CONTROL BY CULTURAL METHODS

Attention to cultural methods can play an important part in reducing the likelihood of *Botrytis* infection. Windbreaks, living or non-living, have been found to be essential in Cornwall. Rows of kale or broccoli planted to filter the prevailing wind are perhaps the commonest protection and are reasonably effective, although severe attacks of Grey Mould have been seen where their use had been overdone and pockets of still air were created. The best non-living windbreak is a matter of dispute ; a very good one, however, is made of vertical 1-inch laths nailed ½—1 inch apart to the supporting structure.

Mechanical injury during cultivations is largely avoidable, but some bruising during picking is inevitable, even with the most skilful of pickers ; with unskilled workers, it is often serious. It is noteworthy, however, that the stump of the flower stalk itself is not one of the most common starting-places for *Botrytis*.

There are serious objections to any attempt to control *Botrytis* by withholding nitrogen, since large flowers with long thick stems, commanding the highest market prices, are produced only on big, well-fed plants. In practice, the best results have been obtained when the nitrogen is balanced by generous supplies of potash, and when much of the nitrogen is given in a form which will persist for a long period—for example, coarse hoof-and-horn.

A very widely spaced crop, like a very hard grown one, is unlikely to suffer severely from *Botrytis* ; the free movement of air round the plants prevents the establishment of a micro-climate suitable for the development and spread of the fungus. Also, wide spacing, by reducing competition for the available food supplies in the soil, renders the yellowing and necrosis of the lower leaves in autumn less likely. As a means of control, however, wide spacing has its limitations : the plant population cannot economically be reduced below a certain level, and anemones become better established in the earlier growth stages when grown close together.

In our opinion, widely spaced rows, not less than 18 inches apart (under average growing conditions) with corms planted in pairs at stations 8 or 9 inches apart (rather than singly at 4 inches), have given the best economic results, although, from the point of view of *Botrytis* control alone, single corms at the wide spacing would be preferable. However, on some soils which pack easily or hold much water during wet periods, the 4-row bed may become a necessity if the ground is not to become set hard as the picking season proceeds. With this system the beds are separated by 22–24-inch paths from which the picking is done. To maintain the number of plants per acre, and also to ensure that all the plants can be reached from the paths, the distance between the rows in the bed is usually reduced in this method of growing to 12 inches. The resultant growth is often so dense that conditions for *Botrytis* are ideal, and losses from Grey Mould often outweigh the advantages of the system. For this reason, it is seldom used in those areas of west Cornwall where *Botrytis* is rife.

It is unlikely that the concentration of the inoculum can be reduced by cultural means below the level at which it becomes a potential source of a *Botrytis* epidemic. Minor hygienic precautions seem to have little effect, but the proximity of other very susceptible crops, such as strawberries, appears to increase the risk of an epidemic appreciably.

CONTROL BY MEANS OF FUNGICIDES : DUSTING TRIAL

The attempted control of *Botrytis* by fungicidal means remains to be considered. Dusting with a 3 per cent tetrachloronitrobenzene (TCNB) dust is often practised, but few, if any, controlled tests have been made. In 1953–54, therefore, a trial was carried out on a holding at Trenarren, near St. Austell, where *Botrytis* is regularly troublesome. This site is in a steep and enclosed combe running in a southerly direction to the sea. It is thus subject to gale damage and, at other times, to high atmospheric humidities. A plantation of Auchincruive Climax strawberries adjoined the anemones.

The anemone field contained thirty-two 4-row beds. In the first fourteen beds the corms were planted singly at 8 inches apart ; in the remaining beds the corms were in pairs at stations 8 inches apart. Throughout the field the rows were 14 inches apart in the beds, with picking paths of 28 inches between the beds. All the corms were planted during the last week of June.

The first eleven beds of corms planted singly were dusted with 3 per cent TCNB dust, the last three beds being left as controls. Where the corms were planted in pairs, there were two dusted areas, of five and ten beds respectively, with a three-bed control between them. These few, but comparatively large, plots were preferred to smaller plots with several replications because, in preliminary trials elsewhere, swamping of the treated plots by infection from the controls had occurred. Four dustings with TCNB were given (on August 28, September 15, October 22–29 and December 10), each at the rate of about 24 lb. per acre.

The first recording of results was made on November 19, but at this date the attack was still negligible. The second was made on December 22, at what was subsequently found to be the peak of the epidemic. Ten groups of ten plants were chosen at random from the treated sections and a similar number from the untreated. The number of plants (or plant-doublets, where the corms were planted in pairs) which bore sporing *Botrytis* visible with a lens, was counted. As a measure of the amount of *Botrytis* damage this criterion is open to serious criticism, especially in that the figure obtained will depend very largely on the weather of the past day or two, but by late autumn there is so much necrosis from other causes in an anemone field that only the presence of visible *Botrytis* enables even the roughest estimate to be made of the damage due to this fungus. As a means of comparing the treated and untreated plots, the method is probably reasonably fair.

The percentages of the plants infected with *Botrytis* on December 22, 1953, and on January 19, 1954—when the epidemic had waned as a result of cooler and drier weather—were as follows :

	Corms Planted Singly		Corms Planted in Pairs	
	Dec. 22	*Jan. 19*	*Dec. 22*	*Jan. 19*
Dusted with TCNB	44	26	72	22
Control	42	22	67	20

In this trial, dusting with TCNB was ineffective. Observations on other holdings, where the whole crop had been treated, have been difficult to interpret because of the absence of controls, but they have certainly indicated that, even when dustings are done regularly from late summer onwards, they do not always prevent the development of very severe attacks when weather conditions favour the fungus. They also show that it is useless to dust with TCNB, or any other fungicide so far used, once *Botrytis* is present in epidemic form.

In the trial at St. Austell the incidence of the disease at the peak of the attack was much higher in the thicker crop which resulted from planting two corms at a station. This was in accordance with our general experience and, indeed, in the absence of effective fungicidal control, wide spacing both within and between the rows appears to be the only practicable way of avoiding serious trouble. This entails, however, a sacrifice in plant population and, therefore, in the number of flowers picked per unit area, and possibly also a loss of quality. Heavy feeding and close growing give better monetary returns in the autumn, and unless good crops are obtained at that time the grower is unlikely in most years to secure fair net returns for the season.

It appears to us, therefore, that although certain cultural practices help to lessen it, the risk of *Botrytis* attack must be taken by those who wish to grow anemones of the highest quality ; and that if an epidemic does occur, there is at present no satisfactory means of checking it.

Thanks are due to Mr. E. A. Griffin of Hallane Farm, Trenarren, St. Austell, for permitting the trial to be made on his crop, and for his co-operation throughout.

EXPERIMENTS ON CONTROL OF BEAN SEED FLIES

by W. I. St. G. Light and H. J. Gould

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Howe, Schroeder and Swenson (1952) recommend combined seed dressings of ¼ ounce *gamma*-BHC and 1 ounce thiram per bushel of seed for the control of Bean Seed flies (*Delia* spp.). They state that the addition of the fungicide is necessary to offset the adverse effects of the insecticide. In a trial at Maidstone in 1954 this combined treatment, and also individual treatments with *gamma*-BHC and thiram, were compared with aldrin dust, at two rates, drilled with seed treated with thiram seed dressing, and with untreated seed. A randomized block layout was used with four replications of each treatment. A 4 per cent methyl cellulose solution at about ½ pint per bushel was used as a sticker for the seed dressings. Each plot consisted of 25 French beans of the variety Blue Lake in a 6-foot row. The beans were sown on June 22 and lifted on July 13 to assess damage by Bean Seed fly larvae. Some losses were caused by slugs and a number of beans were not recovered. The number damaged by larvae to such an extent as to prevent normal development were expressed as a percentage of the total number of beans recovered on each plot, and these percentages were transformed to angles for statistical analysis. The particulars of the treatments and the results were as follows :

Treatment per Bushel of Seed (with ½ pint 4 per cent methyl cellulose as sticker)	Mean Number of Sound Seedlings per Plot	Proportion of Seedlings Attacked by Larvae	
		Degrees (angular transformation)	Percentages
Aldrin dust (1¼ per cent aldrin)			
1 oz. per 10 yd. of drill			
+ thiram seed dressing (1·16 oz.)	21·8	7·1	3·0
without seed dressing	16·0	10·3	6·3
½ oz. per 10 yd. of drill			
+ thiram seed dressing (1·16 oz.)	21·0	6·0	2·1
without seed dressing	17·3	18·1	10·1
Gamma-BHC 0·29 oz.			
+ thiram seed dressing (1·16 oz.)	18·3	23·3	18·2
without thiram	14·5	33·4	30·6
Thiram seed dressing (1·16 oz.)	14·5	37·0	37·4
Control	11·5	41·1	43·5
Significant difference (P = 0·05)	5·7	13·5	—

All treatments, except those with *gamma*-BHC or thiram alone, were significantly better than the control in respect of attack by the larvae. Aldrin dusts gave a better result than *gamma*-BHC seed dressing, although this was only significant when the fungicide was added. The higher rates of aldrin were not significantly better than the lower. The addition of fungicide gave a consistently better result, approaching the 5 per cent level of significance, when the lower rates of aldrin were compared with regard to attack, and the higher rates of aldrin in respect of stand.

To test whether 1¼ per cent aldrin dust in excess of that used in the main trial would be likely to increase damage, a small trial incorporating the dust at 1 ounce per 10 yards of drill and at double and four times this rate, was laid down at Wye on July 2. There was little difference in the stand between any of the treatments.

In a previous experiment in which the beans were sown on May 14 and lifted on June 14 and 15, *gamma*-BHC at about ½ ounce and 1 ounce per bushel, with and without thiram at 2 ounces per bushel, were compared with untreated seed. A treatment of ½ ounce *gamma*-BHC and 2 ounces thiram, using methyl cellulose sticker, and a similar treatment with hand-sowing, were also added. *Gamma*-BHC at ½ ounce did not increase the stand significantly over the control, and with the higher rate the stand was significantly reduced. The addition of fungicide significantly increased the stand, as compared with insecticide alone, and the effect was greater with the higher rate of insecticide. The fungicide alone gave the highest stand—a mean of 80 beans against 58·8 for the control—which was significant at the 1 per cent probability level. All the treatments had significantly less attack than the control, but there were no significant differences between them. It has been thought that hand-sowing of beans dressed without sticker might remove enough dust to reduce protection. This was not the case with ½ ounce *gamma*-BHC and 2 ounces thiram, but it might be so with lower rates.

Our results confirm the findings of Howe, Schroeder and Swenson that insecticides do damage the seed, and that this damage can be offset by the addition of a fungicide. Thiram was also found to reduce the amount of larval attack. This may have been due in part to its insecticidal properties (Guy, 1937). Baylis, Despande and Storey (1943) found that peas sown early, when the soil is damp and wet, and growth is less, are more easily invaded by soil organisms, causing pre-emergence damping off. In the earlier experiment described above, the percentage reduction in larval attack, as assessed, on the seeds treated with ½ ounce *gamma*-BHC and 1 ounce thiram as compared with the control, was 82·6 per cent, against 58·2 per cent for ¼ ounce *gamma*-BHC and ½ ounce thiram in the later experiment. One ounce thiram alone effected a significant reduction in the amount of attack in the first experiment, but was ineffective in the second. This could be due to the higher rates of insecticide and fungicide used in the first experiment, but it seems equally likely that the beneficial effect of thiram lies in its prevention of resulting invasion by soil organisms, whether the initial damage is caused by the insecticide or by larvae.

The greater effectiveness of the row application of 1¼ per cent aldrin dust, as compared with the *gamma*-BHC seed dressing, is probably due to the greater dispersion of toxic material around the seedling, so that protection is not limited to the immediate neighbourhood of the seed. The difference in the insecticide is likely to be less important.

It may be concluded that a combination of 1¼ per cent aldrin dust at ½ ounce per 10 yards of drill and thiram seed dressing at 1 ounce per bushel with ½ pint of 4 per cent methyl cellulose as a sticker, will ensure a good stand in the face of attack by the larvae of Bean Seed flies. A combined dressing containing ¼ ounce *gamma*-BHC with 1 ounce thiram is almost as effective.

Thanks are due to Ditton Court Farm, Ltd., Maidstone, with whose co-operation these trials were carried out.

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AN INSECT PEST REPORTING SCHEME

Contribution from the Conference of Entomologists, National Agricultural Advisory Service, compiled by A. H. Strickland, Plant Pathology Laboratory, Harpenden, Herts, and A. Ibbotson, N.A.A.S., Bristol

In the pest survey work carried out by N.A.A.S. entomologists during the period 1946–51, little account was taken of those static, or permanent, ecological factors which operated at each field site and which probably influenced the behaviour and density of the pests surveyed. Partly for this reason, it was difficult, and in some cases impossible, to interpret the results of these reconnaissance surveys with confidence (Strickland, 1953; Thomas, 1954; White, 1953). At the same time, it was realized that very little information was available on regional and local ecology in relation to pest abundance.

We therefore drafted, in collaboration with the N.A.A.S. entomologists, a scheme whereby a permanent record could be made of some of the static factors pertinent, or thought to be pertinent, to pest activity and abundance at each field visited in the course of routine survey work, and for as many fields as possible visited in the normal routine of advisory duties. This paper gives details of the scheme and of the results obtained over three seasons with regard to the Cabbage aphid, *Brevicoryne brassicae* (L.), the Peach-Potato aphid, *Myzus persicae* (Sulz.), and Frit fly, *Oscinella frit* L.

THE FIELD QUESTIONNAIRE

The Field Questionnaire, or Pest Incidence Report, is shown below. With the exception of three lines at the top and a space for miscellaneous information and remarks at the bottom, the form is of the " question and answer " type, and the answer to any given question is denoted by putting a line through the most appropriate frame. This method has the advantage that fields can be sorted into a limited number of categories based on the " omnibus " terms which are defined below. Every question must be answered, and for this reason the letters " NK " (not known) are framed where an omnibus term would be inappropriate and where a certain lack of information would influence the collation of results.

Section 1—Artificial Conditions

The information recorded on the field questionnaire is grouped into five sections, the first of which relates to the more or less artificial conditions under which the host crop is being grown. There are six main headings to this section :

Type of Agriculture. This refers to the general type of agriculture practised within a radius of 3–4 miles of the field in question. If more than 50 per cent of the farms in the area are ARABLE farms, do they grow ROOTS (R) more than CEREALS (C), or vice versa ? If the agriculture is not arable, it should be : PASTURE (predominantly dairy or stock country with more than 50 per cent of the farms concerned with livestock products and production) ; MIXED (neither predominantly arable nor pasture) ; MARKET (areas in which vegetable crops for human consumption form the major cash crops, (F) where the farms are predominantly greater than 25 acres, or (G) where the majority of holdings are market gardens less than 25 acres in extent) ; URBAN (within a radius of 3–4 miles of a large town or centre of population) ; MARGINAL (marginal land, mostly rough grazing and hill or moorland country, including agricultural land in the process of rehabilitation) ; or FRUIT (more than 50 per cent of the farms growing top fruit and/or hops).

Previous Crop. Was the crop grown the previous season on the field susceptible to the pest being investigated, or not susceptible? Was it GRAMINACEOUS, CRUCIFEROUS, LEGUMINOUS, etc.?

Crop Grown in District. The relative importance of the crop being examined in the district (radius of 3–4 miles) as a whole. It must be either DOMINANT (host crop occupying a greater part of the agricultural land in the district than any of the other main crops, provided this is at least half of the available crop area); ABUNDANT (host crop occupying more than a quarter, but not more than one-half, of the available crop area in the district; COMMON (several crops to be found in the district, but occupying less than a quarter of the available area); or RARE (crop an unusual one for the district). In practice, this classification has been modified by bulking "Dominant" and "Abundant" and referring to fields in both as in INTENSIVE GROWING AREAS. The acreage of the field is noted in one of five classes, ranging from less than 5 to more than 50 acres.

Crop Data. The date on which the field was ploughed and the crop planted. Was planting EARLY, NORMAL, or LATE for the crop and district concerned, and was the growth of the crop at the time of the visit BELOW NORMAL, NORMAL, or ABOVE NORMAL for the district and time of year? The SHAPE OF THE FIELD is noted as LONG AND NARROW (any field which is roughly three times as long as broad, whatever its shape); IRREGULARLY SQUARE (any field which is not more than 2½ times longer than broad, and which is not obviously of irregular shape), or IRREGULARLY OVAL (any field which is not long and narrow, but which is too irregular in shape to be classed as "irregularly square".

Applications to Crop and to Last Crop. For use primarily in connection with pests of fruit and hops. The insecticide section has been left blank so that the chemicals used can be noted. Notes on concentrations, as well as rates of application of manures, can be given at the bottom of the form.

Age of Orchard in years, and **Tree Type** (standard, half-standard, bush, or espalier) complete the information requested in this section.

Section 2—Natural Ecology

The second group of questions refers to the natural ecology of the area in which the field being examined is the central point, and to the situation of the field within that area.

General Topography. The area within a radius of about 3 miles of the field. WOODED and NOT WOODED. The area is wooded if half or more of the non-residential land is woodland. FLAT OR SLOPE (the general configuration of the area either flat or gently sloping, with a maximum difference between the highest and lowest point in the area of 100 feet); UNDULATING (area gently undulating, with a maximum difference between the highest and lowest points of 300 feet); HILLY (no flat ground, but with a maximum difference between highest and lowest points in the area of 1,000 feet); and SCARP (escarpment—ground falling away precipitously on one or two sides).

Local Topography. This is intended to refer to the area within a radius of about half a mile of the field. FLAT (flat, or level, or less than a 1 in 10 slope); VALLEY (enclosed on three sides by higher ground—ground falls away in one direction only); SPUR (top land with ground falling away in three directions with a slope in excess of 1 in 10); and TOP (summit—ground falls away in all directions).

Form of Field. The description of the field itself. WATER MEADOW (field adjacent to a river or stream and subject to seasonal flooding or waterlogging); FLAT (no definite aspect); SLOPE (with a definite aspect); HOLLOW (a bowl—ground rises in all directions from the centre), and SUMMIT (ground falls away in all directions from the centre).

Altitude (below sea level, and in feet above sea level), **Aspect** (the direction in which the greater part of a sloping field is facing), and **Proximity to Coast** (less, or more, than five miles) complete the information asked for in this section.

PEST INCIDENCE REPORT.

PEST			CROP					VAR					
FARM								COUNTY					
DATE					MAP REF.								
TYPE OF AGRICULTURE		ARABLE: (R) (C)			PAST:	MIXED:	MARKET (F) (G)			URBAN	MARG:	FRUIT	
PREVIOUS CROP	SUSCEP:	NOT SUSCEP:			GRAM:	CRUC:	LEGUM:	UMBEL:	SOLAN:	CHENO:	OTHERS	NK	
CROP GROWN IN DISTRICT		DOM:	ABUN:		COMM:	RARE	ACR'GE	—5	—10	—20	—50	+50	
CROP DATA	PLANTING MONTH	PLOUGHING MONTH	PLANTING PERIOD				GROWTH AT VISIT			SHAPE OF FIELD			
			E	N	L		B.N.	N	A.N.	L+N	I. SQ:	I. OV:	
APPLICATIONS	INSECTICIDES						WEED KILLERS			F. Y. M.			
	WINTER	SPRING	POST-BLOSSOM	NONE									
TO CROP							YES	NO	NK	YES	NO	NK	
TO LAST CROP							YES	NO	NK	YES	NO	NK	
AGE OF ORCHARD (YRS.)	—2	—5	—10	—20	+20	TREE TYPE		S	H-S	B	E		
GENERAL TOPOGRAPHY		FLAT OR SLOPE	UNDUL	HILLY	MOUNT	SCARP	LOCAL TOPOGRAPHY		FLAT	VALLEY	SPUR	TOP	
WOODED	NOT W						WOODED	NOT W					
FORM OF FIELD	W-M	FLAT	SLOPE	Hollow	SUMMIT	ALTIT.	BELOW S.L.:	—100	—300	—500	—1000	+1000	
ASPECT	N	N.E.	E	S.E.	S	S.W.	W	N.W.	PROXIMITY TO COAST		—5M	+5M	
SOIL CLASSIFICATION			CLAY	CLAY-LOAM	SILT-LOAM		LOAM	SANDY-LOAM		SAND	CHALK	PEAT	
DRAINAGE	NK	V-POOR	POOR	GOOD	EXCESSIVE		STONES	NONE	GRAV:	S or S	S-O	S-1	S-2
SHELTER	MEAN HEDGE HEIGHT (FT.)				WALLS			TREES		WOODS		NONE	
NORTH	—5	—10	—20	+20	—5	—10	+10	M	F	P	A		
EAST	—5	—10	—20	+20	—5	—10	+10	M	F	P	A		
SOUTH	—5	—10	—20	+20	—5	—10	+10	M	F	P	A		
WEST	—5	—10	—20	+20	—5	—10	+10	M	F	P	A		
DAMAGE	NONE	SLIGHT CHECK	PATCHY	TOTAL FAILURE	POPULATION PER ACRE								

SPECIAL FEATURES CONTRIBUTING TO ATTACK

WEED STATUS

CULTIVATIONS

REMARKS

The Pest Incidence Field Report Form

Sections 3 and 4—Soil and Shelter

The third group of questions refers to edaphic factors on the field which influence plant growth, and hence the pest. The definitions used have, for the main part, been taken or adapted from the U.S. Department of Agriculture Soil Survey Manual for 1951. Definitions for chalk and peat soils have been taken from Hall (1920).

The fourth section refers to the shelter characteristics of the field in terms of mean height along the four quadrants north, east, south and west. The mean hedge height is estimated for each quadrant and the appropriate height frame ticked. Where there are walls or dykes but no hedges, the WALLS frames are used to denote the shelter status of the field. If scattered trees are present in the hedgerows and their canopies are separated on the average by distances greater than their mean height, FEW (F) trees are said to be present. If trees are separated by less than their average height, MANY (M) is the correct description. WOODS are defined as PRESENT (P) if a wood or coppice is adjacent to a field boundary, even if it does not extend the whole length of one side.

Section 5—Economic Damage

The last section comprises the minimum amount of information required on the economic damage being done by the pest under investigation. If an estimate of pest density has been made, this is given in the frame POPULATION PER ACRE.

Damage. NONE (no visible damage to crop); SLIGHT CHECK (where the plant stand has not been appreciably reduced, but growth has been temporarily reduced by the pest); PATCHY (where the plant stand has been appreciably reduced, but not sufficiently to necessitate resowing the whole field); TOTAL FAILURE (80 per cent or more of the crop severely attacked, or where the entire crop has to be written off or ploughed under).

In practice, these definitions have not been completely satisfactory, largely because of the wide range of pest densities which, dependent on factors not yet fully understood, can result in no damage one season and appreciable damage in the next, or in the same season at a different time. Further, there has been a tendency for observers to class fields with widely differing pest densities as " slightly checked ".

USE OF THE FIELD QUESTIONNAIRE IN 1950–53

Completed questionnaire forms are sent by provincial entomologists to the Plant Pathology Laboratory for collation. The data are there transferred on to punched cards of the " Paramount " type for ease in sorting in respect of the many variables recorded. The first form was filled in during April 1952, and in the period up to April 1954 some 900 forms, referring to 89 pest species, were completed, including 170 forms relating to two species which were investigated in some detail in 1950 and 1951. Of these forms, 349 refer to fields of Brussels sprouts which were surveyed, or otherwise visited, for Cabbage aphid, 120 refer to potato fields on which an aphid survey was conducted, and 223 refer to fields of cereals which were visited in connection with work on Frit fly, leatherjackets, wireworms and Wheat Bulb fly.

THE CABBAGE APHID

For each of the 349 fields of Brussels sprouts an estimate of Cabbage aphid density was made between September and October when this pest reaches its

peak population. These estimates have been expressed in terms of Log(N+1) aphids per three-leaf sample (Strickland, 1954), and an attempt has been made to assess the effects of some of the factors noted on the field forms on the peak density of this aphid.

In attempting to determine the influence of ecological factors on pest populations from data of the type recorded on the field forms, it is important to make due allowance for association between the different factors observed. Further, great caution is necessary when drawing conclusions from observational data because of the many factors which may be of importance but which cannot be allowed for in practice. We were, for instance, interested to see that there is apparently a close relationship between Cabbage aphid peak density and field acreage—the larger the field, the more likely it is to suffer severe attack. However, on drawing up a table in which acreage was plotted against intensity of sprout-growing regardless of aphids, it was clear that sprouts tend to be grown on larger fields in intensive areas, rather than in areas where they are not a dominant or abundant crop. These results are shown in Table 1, which includes data on the shelter characteristics of sprout fields in the intensive and less intensive growing areas.

TABLE 1

INTERRELATIONSHIPS OF SOME ECOLOGICAL FACTORS IRRESPECTIVE OF APHID DENSITY

	Percentage of Fields in each Type of Growing Area		
	Sprouts a Dominant or Abundant Crop	Sprouts a Common Crop	Sprouts a Rare Crop
Field Acreage 0–5	24	59	53
5–10	38	29	29
Over 10	38	12	18
(Number of Fields)	(71)	(179)	(55)
Fields with no shelter at all	18	21	10
Shelter on one or two sides	18	38	42
Shelter on three, or all four, sides	64	41	48
(Number of Fields)	(73)	(179)	(57)

Wherever they are grown, Brussels sprouts tend to be cultivated on fields which are to some extent protected by hedgerows, and this is more marked in the intensive growing areas. Obviously, in the light of these results it is not valid to compare Cabbage aphid populations with intensity of sprout-growing independently of field acreage, and it is clear that shelter must also be taken into account, particularly with fields in intensive growing areas. In view of these relationships a composite table has been prepared in which the Cabbage aphid density data have been broken down into groups consistent with the rather small total number of fields available for analysis (Table 2).

With two exceptions (both in the " Rare ", 101–300 feet group), aphid density was higher on fields more than 5 acres in extent than on the smaller fields. This appears to be unaffected by shelter, altitude, and intensity of sprout cultivation. In one of the exceptions only three fields were available for the comparison, but in the other twenty-five fields were involved, of which nine were in Wiltshire on the edge of the intensive Evesham brassica zone, two were in Gloucestershire, and the rest were in Northumberland, Westmorland, Glamorgan and Monmouth. If the twenty-five fields are broken down into groups of counties surveyed by five different observers, the trend is still apparent. Other factors have been tested to try and explain this reversal of trend, but no reasonable explanation has been found.

With three exceptions ("Rare", over 300 feet group, and "Common", 101–300 feet group), aphid density was higher on fields with some shelter than on those with no shelter at all. In the first instance, the value for unsheltered fields is based on a single observation and cannot be relied upon as giving a true picture of the position. Again, in the second the number of unsheltered fields is too small to strike a reliable mean. It is evidently reasonable to conclude that the presence of shelter enables the aphids to reach a higher density than they can in its absence, and that this effect is apparently not influenced by field size, altitude, and intensity of cultivation.

TABLE 2

THE EFFECT OF INTENSITY OF SPROUT GROWING, FIELD ACREAGE, PRESENCE OR ABSENCE OF SHELTER, AND ALTITUDE ON ESTIMATED PEAK CABBAGE APHID DENSITY, EXPRESSED AS MEAN LOG (N+1) APHIDS PER SAMPLE

		Intensity of Sprout Cultivations					
		Dominant or Abundant		Common		Rare	
		Under 5 Acres	Over 5 Acres	Under 5 Acres	Over 5 Acres	Under 5 Acres	Over 5 Acres
Altitude 0–100 feet	No Shelter ..	—	—	1·50	1·64	—	—
	No. of Fields ..	—	—	20	9	—	—
	Some Shelter ..	1·56	1·74	1·55	1·79	1·17	2·21
	No. of Fields ..	2	12	47	25	4	4
Altitude 101–300 feet	No Shelter ..	1·48	2·10	1·64	1·85	1·04	0·69
	No. of Fields ..	1	5	5	3	1	2
	Some Shelter ..	2·00	2·56	1·28	1·33	1·67	1·18
	No. of Fields ..	10	11	22	21	11	14
Altitude over 300 feet	No Shelter ..	—	2·11	—	1·04	2·04	—
	No. of Fields ..	—	5	—	1	1	—
	Some Shelter ..	1·52	2·91	—	1·41	1·55	1·65
	No. of Fields ..	2	14	—	10	9	5

There is an indication in the table that fields in areas where sprout cultivation is dominant or abundant support higher aphid populations than fields in areas where sprouts are less intensively grown. There are no clear trends shown over the altitude range under consideration, and it is evident that more field records and a greater altitude range are needed before this point can be looked at.

Bonnemaison (1950) suggests that the fecundity of the Cabbage aphid is low in areas of high humidity. It is therefore of some interest to see whether there is any consistent difference in aphid density on fields close to the sea, compared with inland fields. The result of this investigation is shown in Table 3.

TABLE 3

THE EFFECT OF PROXIMITY TO THE SEA ON ESTIMATED MEAN LOG (N+1) PEAK CABBAGE APHID DENSITY IN AREAS WHERE SPROUT CULTIVATION IS COMMON

	Size of Field	
	Less than 5 Acres	More than 5 Acres
Within Five Miles of the Coast	1·43	1·49
Number of Fields	54	22
More than Five Miles from the Coast	1·56	1·67
Number of Fields	40	36

This table has been compounded from the 152 "Common" fields which were surveyed at an altitude below 300 feet. There is an indication that higher peak populations tend to occur on inland fields, and field size and shelter do not appear to influence this trend.

THE PEACH-POTATO APHID

Detailed ecological information was obtained for potato crops in the South-Western Advisory Province between 1950 and 1953. The same forty farms were visited each year, always in the last 10 days in June. *Myzus persicae* density was assessed in a small area of about an acre in each maincrop of potatoes. Apart from siting this area more than two or three hedge heights away from the headland, it was taken as nearly as possible at random in the field. Aphids were counted on one upper, one middle, and one lower leaf on the main stem of each of 50 plants in two traverses of 25 plants. The records will be considered in full elsewhere, but a summary of the results is given here to illustrate the use of the reporting scheme.

Since careful field counts were made in this work, it has been possible to express density in terms of mean Log (N+1) aphids per traverse and attach standard errors to these estimates. In 1952 and 1953 the mean traverse populations of 1·75 and 1·74 did not differ significantly, and it has been possible to bulk the records for these years, giving a total of 80 fields which have been grouped according to altitude (below and above 500 feet), shelter (field exposed if no shelter more than five feet high was present), planting date (early, normal, and late for the district and year), and growth type (haulm meeting along and between the rows = closed ; haulm meeting only along the rows = open ; haulm not meeting, plants discrete = sparse).

TABLE 4

THE EFFECT OF PLANTING DATE, GROWTH OF THE HOST PLANT, ALTITUDE, AND SHELTER ON MEAN LOG (N+1) POTATO APHID DENSITY PER TRAVERSE OF 25 PLANTS

Planting Date	Growth Type	Altitude below 500 Feet		Altitude above 500 Feet	
		Sheltered	Exposed	Sheltered	Exposed
Early	Closed	2·68	0·00	—	—
	No. of Fields	8	1	—	—
	Open	2·17	—	1·96	1·80
	No. of Fields	1	—	1	2
	Sparse	—	—	—	—
	No. of Fields	—	—	—	—
Normal	Closed	2·46	—	1·81	—
	No. of Fields	10	—	2	—
	Open	2·09	1·70	—	1·55
	No. of Fields	10	7	—	3
	Sparse	—	0·97	1·57	0·94
	No. of Fields	—	4	2	2
Late	Closed	2·10	0·80	—	—
	No. of Fields	2	1	—	—
	Open	2·29	1·39	2·04	1·63
	No. of Fields	3	4	2	1
	Sparse	1·84	0·77	1·66	0·47
	No. of Fields	3	4	2	5

The distribution of fields between these groups was far from equal, as can be seen from the partial breakdown of the data given in Table 4. Certain trends are indicated in this table, although the small number of fields in any sub-group necessarily limits the deductions which can be made with confidence. In the first place, open growth supports a higher density of aphids than sparse growth in all sub-groups for which comparisons can be made. Secondly, sheltered fields have higher aphid populations than exposed fields ; and thirdly, early planting tends to result in higher populations than normal or late planting.

These indications seem to hold for all sub-groupings and it is reasonable therefore to bulk the data for overall comparisons. In this respect, 46 of the fields were sheltered and 34 exposed, giving mean aphid densities of 2·27 and 1·14 respectively—a difference which is significant at a probability of 0·01. Similar tests showed that fields below 500 feet supported higher populations than fields at a greater altitude ; early-planted crops had more aphids on them than those planted late ; and the 34 fields in which growth was closed had significantly more aphids than the 22 fields on which growth was sparse.

A further comparison has been made of the exposed and sheltered fields in relation to the two altitude classes. About one-half of the sheltered fields below 500 feet were planted at the normal time, and the rest were equally early or late. All but one of the early crops were closed, while none of those planted early or at the normal time was sparse. Crops planted late were equally closed, open, and sparse. The fields were therefore grouped into four categories for comparison, and differences in aphid density were found to be not significant, though there was a tendency for early-planted closed crops to be more heavily infested than normally-planted open crops.

Only one of the exposed fields below 500 feet was planted early, and only 2 crops were closed, compared with 20 closed crops in the sheltered fields. The rest were either normal- or late-planted and more or less equally divided between open and sparse growth. There was a group of 7 normal open crops which could be compared with the corresponding crops in the sheltered class, and as the late-planted crops were more or less equally closed, open, or sparse, it seemed reasonable to compare the bulked late crops on the sheltered and exposed sites. There were significant differences between the mean aphid densities on normal open crops in exposed and sheltered fields, as well as between the bulked late crops in exposed and sheltered fields. There is therefore some evidence that the relationship between population density and the amount of shelter is a real one. There was no indication that differences in planting date were associated with differences in numbers of aphids, but a clear indication that fewer aphids occurred on sparse crops.

Of the 25 fields above 500 feet, only two were closed, and only three were planted early. This left 17 fields with crops distributed between the normal open sparse and late open sparse, groups. Since there were no closed crops, it was only possible to test altitude differences between bulked open and sparse crops, and the means of these groups did not differ significantly, although there was a significant difference associated with exposure from the comparison of late open sparse crops from exposed and sheltered sites. There seemed to be little difference between the rest of the populations above 500 feet after the exposed late open sparse crops had been eliminated. Thus most aphids occurred on sheltered crops which were meeting along and between the rows, while least occurred on sparse exposed crops.

FRIT FLY

Of the 223 cereal fields on which some information about Frit fly is available, one was a dredge corn crop, three were rye crops, 16 were under barley, 99 under wheat, and 104 under oats, so that there are as yet scarcely enough fields of any one crop to warrant detailed classification, especially since no pest density measurements were made on these fields and it is only possible to classify them in relation to the amount of damage assessed by each observer as none, slight check, patchy, or total failure. The results (Table 5) indicate that consistent trends can be detected even when a doubtless highly inaccurate assessment is made of pest activity on each field.

TABLE 5

TILLER ATTACK BY FRIT FLY ON OATS AND WHEAT

		Size of Field					
		Less than 5 Acres		5–10 Acres		Over 10 Acres	
		Per-centage	No. of Fields	Per-centage	No. of Fields	Per-centage	No. of Fields
No Damage	Oats ..	28	5	27	10	47	10
	Wheat ..	88	7	73	24	77	30
Slight Check	Oats ..	50	9	40	15	19	4
	Wheat ..	12	1	21	7	17	6
Patchy	Oats ..	11	2	22	8	24	5
	Wheat ..	—	—	3	1	6	3
Total Failure	Oats ..	11	2	11	4	10	2
	Wheat ..	—	—	3	1	—	—
	Oats ..	100	18	100	37	100	21
	Wheat ..	100	8	100	33	100	39

There is a clear difference in the extent to which oats (mostly spring varieties) and wheat (mostly winter varieties) are attacked by Frit fly, which is to be expected in view of the known habits of this pest. It is of some interest that these data indicate a trend between attack (as measured by the damage categories) and field size similar to the Cabbage aphid results in Table 2. All of the patchy and severely attacked wheat fields exceeded 5 acres in area, as did 19 of the 23 oat fields.

CONCLUSIONS

Sufficient data are available to show that this reporting scheme enables differences in pest density in relation to agricultural ecology to be detected. The scheme might, in time, provide a basis for precautionary advisory work. But for the present it is sufficient to emphasize that confirmation of the trends shown by the data in Tables 2, 4 and 5 must be obtained, either by properly designed surveys or by field plot experiments on an adequate number of sites. If, by alterations in farming practice, such as a reduction in hedgerows and field size (perhaps by strip cultivation in large fields), pest densities can be reduced, resulting in a decrease in economic damage, then abundant evidence must be obtained before this advice can be given to the farming community.

We should like to express our thanks to all those individual members of the National Agricultural Advisory Service who have co-operated in this work.

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CHALKY DRY ROT OF FREESIA CORMS

by E. W. BUXTON*

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Early in 1953, I received from the National Agricultural Advisory Service at Cambridge several rotted freesia corms, many of which had vascular rots similar to those reported in gladiolus corms (Buxton and Robertson, 1953). The diseased corms showed the characteristic vascular decay and severe rotting of the basal plate. Brown lesions were distributed over their surfaces and pockets of decay were developing in the ground tissue, which was hard and friable, in that it crumbled away from the rotted region. These symptoms resemble those described on American material by Taubenhaus and Ezekiel (1933), who called the condition " chalky dry rot ". Fusaria were readily isolated from the dry rotted vascular tracts and from the junction of the vascular and ground tissue of the corms. All the isolates were indistinguishable in culture from *Fusarium oxysporum* Fr., as described by Snyder and Hansen (1940).

INOCULATION EXPERIMENTS

While studying diseases of gladiolus caused by Fusaria, freesias were inoculated with two cultures of *F. oxysporum* Fr. f. *gladioli* from diseased corms of gladiolus and three cultures of *F. oxysporum* Fr. from diseased freesia corms. Two freesia varieties, Maryon and Beauty, were planted in pots containing unsterile John Innes potting compost, and the pots were kept in a heated glasshouse. The Fusaria were grown on 3 per cent cornmeal sand which was diluted five times with clean sand and added to the pots at planting time in early October. The number of plants (out of eight tested in each set) which showed premature yellowing of the leaves and associated corm rotting symptoms were as follows :

Source of Inoculum	Plants Showing Premature Yellowing of Foliage		Corm Symptoms after Six Months' Storage
	Maryon	Beauty	
Corm core of yellowed gladioli ..	5	4	Vascular rot and rotting of basal plate
	5	6	
Corm core of freesia showing chalky dry rot	7	6	Vascular rot and chalky dry rot
Corm core of freesia showing vascular browning and some chalky dry rot ..	0	5	
Surface lesion of freesia corm ..	0	6	
Controls. No inoculum	0	0	No symptoms

The corms were lifted in March and stored in the laboratory. Diseased material plated at this stage yielded isolates of *F. oxysporum* that were identical in cultural characteristics with those used as inoculum. After six months' storage the remaining corms were again examined and diseased fragments were plated. Corms from all plants whose foliage became prematurely yellow yielded *F. oxysporum*, together with a few Penicillia. Chalky dry rot had developed, both in the corms inoculated with isolates originally taken from chalky corms and, to a slightly less extent, in those from corms not originally chalky. No chalky dry rot was detected in corms inoculated with isolates originally obtained from gladiolus. The results suggest that *F. oxysporum* can be considered to be one cause of chalky dry rot of freesia corms in this country. Corm rot and premature yellowing of freesia have been described in America

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by Taubenhaus and Ezekiel (1933), and in Denmark by Sennels (1951), who listed several Fusaria that rot freesia corms, notably *F. bulbigenum*, *F. martii-minus*, *F. moniliforme*, *F. oxysporum* and *F. solani* (*sic*).

McClellan (1945) showed that *F. oxysporum* from corms of yellowed gladiolus could cause yellowing of freesia foliage, whereas McCulloch (1944) and Taubenhaus and Ezekiel (1933) could not infect freesia with isolates from gladiolus. The results of my tests resemble McClellan's. They also suggest that different freesia varieties differ in their susceptibility to different isolates of *F. oxysporum*. An additional test of mine in which freesia were inoculated with *F. oxysporum* Fr. f. *cubense* (from wilted banana) was not successful, although this isolate again is culturally indistinguishable from the isolates pathogenic towards freesia. The inoculated plants remained healthy. These results serve to illustrate the degree of specificity of pathogenicity shown by the various members of the form-species *F. oxysporum*.

My thanks are due to those members of the N.A.A.S. who kindly sent me diseased material, and to Dr. J. Rishbeth of the Botany School, Cambridge, who provided the culture of *Fusarium oxysporum* f. *cubense*.

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DAMAGE TO ROSES AND LETTUCE BY 2,4-D DRIFT

Morphological effects on plants due to damage by growth regulator weed-killers were described in this JOURNAL by K. Holly (*Plant Pathology*, 1954, **3**, 1–5). Two further specific examples of such damage are illustrated in this issue. On rambler roses (Plate II, 1), drift of 2,4-D from corn spraying in an adjacent field caused narrowing of the leaflets and increase in depth of marginal serrations, resembling the effect already illustrated on the leaves of tomatoes (*loc. cit.*). On lettuce (Plate II, 2), also damaged by 2,4-D drift, the margins of the inner leaves were rolled back and the laminae were thickened, giving a " dog's tongue " effect, and some of the outer leaves were cupped, due to constricted growth of the leaf margins.

Plant Disease Survey

NEW OR UNCOMMON PLANT DISEASES AND PESTS IN ENGLAND AND WALES

Perithecial Stage of *Didymella lycopersici* on Tomatoes. The perfect state of *Didymella lycopersici* Kleb. was found at Alcester, Warwickshire, on November 4, 1954, on an outdoor crop of tomatoes severely affected by stem rot. The perithecia occurred at the upper edge of a basal stem lesion (3–4 inches long) which extended down to soil level and from which the cortex had rotted away. They were thus in a similar position on the stem to those described by Hickman (*Nature, Lond.*, 1944, **154,** 708), who first recorded the perithecia of the fungus in Britain, also on an outdoor crop. Isolates from single ascospore cultures have been inoculated into tomato stems and typical lesions were formed bearing pycnidia of the imperfect stage of the fungus, *Diplodina lycopersici* Hollós. These observations were made in the course of my work at the National Vegetable Research Station, Wellesbourne, Warwick.

DOROTHY E. FISHER

Damping-off and Leaf Blight in Azalea. During the autumn and winter of 1953–54 severe damping-off of *Azalea indicum* and *Azalea japonicum* cuttings was experienced on a nursery near Norwich. The attack was mainly above ground level and the mycelium of *Rhizoctonia solani* Kühn could be seen covering the leaves and shoots. Several leaves were sometimes matted together by the growth of mycelium. The same fungus was found causing a destruction of the foliage in young plants crowded together on the floor of the greenhouse. The typical appearance of the affected plants is shown in Plate III, 2. A very characteristic feature was the way in which the dead leaves remained attached to the stems by a few strands of mycelium. Control of this disease was obtained in the striking frames by dusting the cuttings with a chloronitrobenzene dust. The same trouble has been recorded from America (Raabe, R. D., *Quart. Bull. Amer. Rhododendron Soc.*, 1954, **8,** 82–6).

I. F. STOREY

***Pergamasus* sp. on Potato Roots in Scotland.** In July 1954, during the usual inspections of growing crops of potatoes in Angus, the eggs of a species of *Pergamasus* were found adhering to the roots of potato plants. The mites were observed in localized areas in the crops and some plants had 30–40 eggs on their roots. The eggs were incubated in the laboratory, where larvae emerged after about four days. Some ten days later these gave rise to protonymphs, which were sent to the British Museum for identification. Although Gamasid mites are free-living and are not normally injurious to plants, eggs when attached to the potato roots closely resemble the immature cysts of the Potato Root eelworm, *Heterodera rostochiensis*, and it was feared that confusion might arise due to this similarity (Plate III, 1). *H. rostochiensis* cysts are, however, usually firmly attached to the root system, and by July they have, in most cases, arrived at the yellow stage. The mite eggs differed in that they were easily dislodged and they were white and translucent. Adults of another species of mite, *Rhizoglyphus echinopus* Fum. & Rob., were found in the soil adhering to the roots, and are of interest in that this species frequently infests plant bulbs and is of horticultural importance.

MARY BEVERLEY-BURTON

Privet Thrips on Imported Plants. In early November 1954, the leaves of a consignment of Dutch privet were found to be unusually puckered and discoloured. At first this was thought to be due entirely to the plants overheating in the ship. On closer inspection, however, small active black thrips were found on the foliage, and it was noticed that the upper epidermis of some leaves had the puckered silvery marks typical of attacks by the Privet thrips, *Dendrothrips ornatus* (Jabl.). Specimens were sent to the Plant Pathology Laboratory and the identification was confirmed by Mr. P. Aitkenhead. The Privet thrips is well known in Europe and North America as a minor pest on privet and lilac. In Great Britain, only one field infestation had been found (*see* V. W. Fowler, *J. R. hort. Soc.*, 1954, **79,** 405) and odd specimens have been collected on three other occasions. This is the first time that Privet thrips has been intercepted on imported plants.

J. W. HANCOCK

The Artichoke Tuber Aphid on Chrysanthemums. Specimens of wilting and dying chrysanthemum plants were received in October 1954, from Mr. W. J. Moyse of the N.A.A.S. at St. Mary's, Isles of Scilly. The damage proved to be due to root attack by *Trama troglodytes* Heyden s. lat. (*vide* Eastop, V. F., *Trans. R. ent. Soc. Lond.*, 1953, **104,** 385–413). This aphid was recorded by Eastop on *Chrysanthemum maximum*, but it does not appear to have been recorded on *Chrysanthemum* cultivars in this country, nor by Patch in her " Food Plant Catalogue of the Aphids of the World " (*Bull. Me agric. Exp. Sta.*, No. 393, 1938). In spite of the lack of records, this aphid does not appear to be uncommon on chrysanthemums in the south-west of England. I have specimens confirming attacks at Prawle, Devon, in November 1945, and at Dawlish, Devon, in October 1949.

H. G. MORGAN

Selective Damage by Badgers in an Oat Trial. In August 1953, at Codrington in Gloucester, selective damage by badgers was observed in the plots of a spraying trial against Frit fly in Star oats. There were sixteen plots, each 12 drills wide × 19 yards long, in a randomized block arrangement. The plots which had been sprayed with DDT, both at tillering and at panicle-burst ripened 7–10 days before the rest, and promised the heaviest yield. These plots were trampled quite flat by badgers and all the panicles were stripped. Control plots, and those sprayed later, after the panicles had emerged, were tunnelled by the animals, but the panicles—even those of plants trodden into the track ways—were untouched. Two dung-pits were found, one at either end of the experimental area, and the faeces in them were found to be composed largely of oat husks. The state of the faeces at successive inspections showed that the badgers—which probably came from a set some three-quarters of a mile from the experiment—paid more than one visit to the area, and used the same dung pit each time. The experiment was situated just below the brow of a slight ridge, between 15 acres of spring wheat in much the same stage of maturity and 5 acres of kale, but neither the wheat, nor any other cereal crop, at least within one mile of the set, showed any signs of similar damage.

A. IBBOTSON

(2548) Wt. 45 K.9 6/55 Hw.